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Metabolic and Cardiopulmonary Responses to Sanding with Right Dominant Hand

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An investigation of metabolic and cardiopulmonary responses to sanding was performed as treatment activity in occupational therapy with 2 factors: angle and speed. Normal young female subjects (n = 7) exercised at speed of 15, 30 and 60 cycles/min. in 3 phases (angle of 0, 15 and 30 degrees) on the basis of sitting rest basal position. Mean values of expiratory volume(VE), expiratory tidal volume(TVE), respiratory rate(RR), Mets, heart rate(HR), systolic and diastolic blood pressure and pressure rate product(PRP) were determined at each phase. Mean value of Mets as maximal load did not reach more than 2.15, which corresponds to light motion as 30-minute sitting on a chair. Except systolic blood pressure and TVE, each variable increased with the faster speed at each phase. In general the responses to differences among the angles were not proved to be significant statistically. These data suggest that sanding exercise as treatment for ischemic heart diseases and cerebral vascular accidents represents the clear numerical value of Mets, and that a further study should be carried out with more factors, for example, weight of sanding block and sanding with two hands.

Key words
Metabolic and cardiopulmonary responses,
Sanding,
Right dominant hand,
Angle and speed,
Young female.

INTRODUCTION

Ischemic heart diseases as well as cerebral vascular accidents in the last several decades have been growing(1); a variety of types of evaluation of ability have been developed as phased programs for the rehabilitation of disabled adult persons(2). Our country will, moreover, come into the most aging society that has ever been experienced. It could be predicted that the number of the old disabled with these diseases will be greater(3,4).

Studies based on exercise physiology are made even in clinical places, but studies with metabolic and cardiopulmonary responses to an activity in occupational therapy have hardly performed. Therefore, it is a fact that the phased program of sanding in the metabolic and cardiopulmonary level exceedingly depends upon each therapist's experience and clinical skill. Because our activities of daily living consist of a variety of factors, it is difficult to build up with definite numerical

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value. Even in several papers(5-8) focussed on sanding as treatment exercise, however, the treatment activity is carried out under one defined condition: either an angle or speed. Furthermore, the items examined are few like blood pressure, heart rate or respiratory rate.

Therefore, the study of graded sanding with load in occupational therapy included both ventilatory and cardiometabolic functions under the two conditions with angle and speed will be of value in the clinic.

From this point of view, a preliminary step to rehabilitation of the aged started with definite numerical value. This paper is focussed on the measurement of ventilatory and cardiometabolic functions in sanding and on the physiological response to exercise load with angle and speed.

SUBJECTS AND METHODS

1. Subjects

Seven healthy female students from the department of Occupational Therapy at Kobe University, School of Allied Medical Sciences, volunteered for the study. They were all physically active, but did not take part in athletics regularly. Characteristics (mean ±SD) of the subjects were as follows: age, 18 ±0.6yr, weight, 48 ±4.4kg and height, 153 ± 3.5cm. The exercise was explained in detail to every subject. Medical examination showed that all subjects appeared clinically to be free of diagnosable cardiopulmonary or other disorders which might contraindicate the exercise.

2. Instruments

As phased physical load a sanding set(SOT-1801, Sakai Iryo) and a sanding block for one hand(SOT-1803, Sakai Iryo) were used. The oxygen concentration of the expired air were analyzed by a medical gas analyzer(MG-360, Minato Medicals) and recorded on a recorder(R56, Rika Electronics). The volume of the expired air was recorded electronically from a generator attached to a spirometer(RM-200, Minato Medicals). These were connected with computer(PC8801, Nippondenki) for data analysis.

Arterial blood pressure was automatically recorded every minute by an electrical sphygmomanometer(STBP-680, Nippon Colin). The electrocardiograms were recorded and observed by a telemeter(Fukuda Electronics), which continuously measured the subject's heart rate from her wave form.

3. Methods

All subjects had had no food or nothing to drink for two hours preceding the exercise. This was carried out in an air-conditioned laboratory at a temperature between 20 and 25℃ and humidity was maintained between 60 and 70 %. The requirements for each of the four phases were as follows:

Phase 1, seated at rest on a straight back chair in the position of exercise. The subject sat before a table 80 cm high, with his right forearm resting on the table and her back supported by the chair.

Phase 2, sanding with horizontal level(O degree). The subject sanded a white pine board, clamped to the table top, with a one handed sanding block

weighted with 0.67kg. weight and no sandpaper. The subject held the handle of the sanding block and moved the arm with complete extension and flexed it to the nearest side of the table. The subject sat with her back against the back of the chair. Therefore, there was no trunk motion during this exercise. Sanding went on for three minutes with metronome to 15, 30 and 60 cycles of exercise per minute. The subject took a three-minute rest between each activity.

Phase 3, sanding at an angle of 15 degrees. The exercise condition was the same as phase 2. The sanding sequence was also at 15, 30 and 60 moves per minute. The rest time after each activity continued three minutes.

Phase 4, sanding at an angle of 30 degrees. The same posture and move at the same rate of 15, 30 and 60 cycles per minutes were carried out during exercise. Three minutes were also taken as rest between each activity.

4. Data Analysis

As index of ventilation function, expiratory volume(VE), respiratory rate(RR) and expiratory tidal volume(TVE) were considered. The parameters of cardiometabolic function, Mets(metabolic units, VO_2 (ml/min)/3.5(ml/min/kg)/weight(kg)), heart rate, blood pressure and pressure rate product(PRP, systolic arterial pressure $\times$ heart rate) were used.

The results obtained were considered to take the average value of data of each three-minute exercise.

The statistical considerations were given to % changes in VE, RR, TVE, Mets, heart rate, blood pressure and PRP, with the data of sitting rest condition as 100%. All of these data were shown with mean value and standard deviation in figure 1 to 7.

RESULTS

The four phases of metabolic and cardiopulmonary responses to sanding were standardized on 7 healthy female students with a total of 10 series of exercises. All subjects took part in all four phases of the exercise and every subject served as her own control of the relation of one phase of the exercise to any other phase. She was, however, on the lookout for the correct moves per minute to a metronome rhythm. The effect of the exercises on the various parameters of responses to sanding were represented as a percentage change from the sitting rest basal position, used as the reference position. These relative changes were tabulated in Table 1 and Table 2, and diagrammed in Figure 1 to 7. In all the tables and figures, the mean values of the parameter measured and their standard

Table 1: Mean variance of 4 parameters (TVE, VE, RR, METS) from values during sitting rest basal position

		TVE	VE	RR	METS
Phase 1					
sitting rest		100±17	100±12	100±17	100± 6
Phase 2					
Angle (degree)	Cycles				
0	15	110±22	108±14	100±18	118±12
	30	114±16	124±15	107± 7	139±23
	60	127±12	149±16	122± 8	175±30
Phase 2					
15	15	114±20	111±13	98±17	125±14
	30	122±20	124±11	101±13	148±27
	60	120±13	152±16	125± 7	183±33
Phase 3					
30	15	121±27	109±13	91±17	128±18
	30	110±17	128±11	115±13	145±22
	60	133±22	170±17	129±22	207±40

Variations from basal value were calculated individually for each subject. Data are rounded to the nearest whole number.

deviations are shown.

1. Ventilatory Function

Figure 1 illustrates the change of every phase of expiratory volume(VE) in 7 subjects. In the second to the fourth phase at the defined angle, the more cycles increase, the larger the values get. In every phase the value gets 11 to 12% high in proportion to the increase of the moves, except 13% in the change from 30 to 60 cycles in Phase 3. The changes in the last grade of Phase 2, 3 and 4 increased about 1.5, 1.5 and 1.7 times respectively.

Figure 2 shows the percentage change of expiratory tidal volume(TVE). The values from 30 to 60 of Phase 2 and from 15 to 30 of Phase 3 decrease. The other grades get 11 to 12 % higher than the former one. The values of the last grade of Phase 2 to 4 increase about 1.3, 1.2 and 1.3 respectively as much as the sitting rest basal position. These three values are not almost different from phase to phase.

As shown in Figure 3, the changes of every grade in each phase are almost the same as in VE and TVE. The difference from the previous data shows that the mean values of 15 moves in

Table 2: Mean variance of 4 parameters (BP(sys. dia.), HR, PRP(× 1000)) from values during sitting rest basal position

		Blood Pressure		Heart Rate	PRP
		Sys.	Dia.		(×1000)
Phase 1					
sitting rest		100± 4	100±11	100±14	100±12
Phase 2					
Angle (degree)	Cycles				
0	15	109± 6	100± 9	112±16	121±17
	30	113± 6	107± 7	114±14	128±14
	60	116± 7	108±11	123±15	142±20
Phase 3					
15	15	112±12	101± 9	109±16	123±21
	30	110± 7	109± 8	117±13	128±13
	60	120±13	109± 6	128±13	154±23
Phase 4					
30	15	111±12	103± 5	111±14	123±13
	30	114± 6	110±13	121±13	138±11
	60	122±11	114± 8	134±16	163±21

Variations from basal value were calculated individually for each subject.
Data are rounded to the nearest whole number.

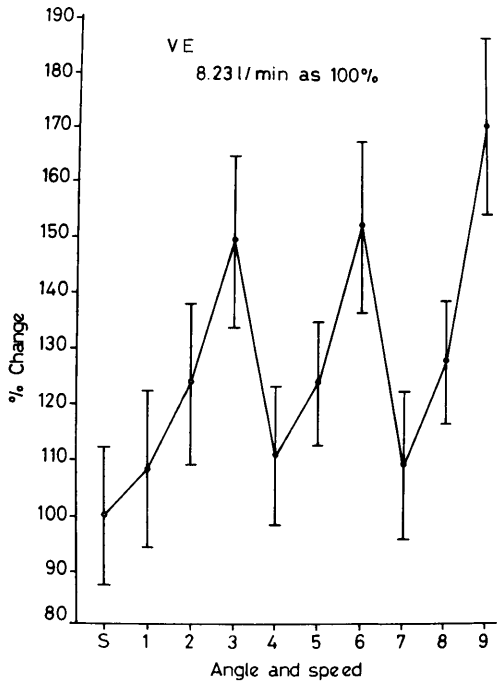


Figure 1. Variation of expiratory volume (VE).
At the defined angle, the more cycles increase, the larger the values get.

S : sitting rest.
1 : 0 degree, 15 cycles.
2 : 0 degrees, 30 cycles.
3 : 0 degree, 60 cycles.
4 : 15 degrees, 15 cycles.
5 : 15 degrees, 30 cycles.
6 : 15 degrees, 60 cycles.
7 : 30 degrees, 15 cycles.
8 : 30 degrees, 30 cycles.
9 : 30 degrees, 60 cycles.

Phase 2 and Phase 3 are smaller than that of the sitting rest position.

On the basis of the above-mentioned result, RR rather than by TVE is considered to regulate the variation of VE. The mean value of the last grade in Phase 3 is, however, apt to show larger than that of any other one.

2. Cardiometabolic Function

Figure 4 illustrates the variation of Mets. In every phase the mean values increase with the multiplication of the number of cycles. Concerning the relative percentage change in the last grades of each phase, Phase 2, Phase 3 and Phase 4 indicate the increase of 17, 18 and 20 % respectively against the basal position. The rate of increase is the greatest in Phase 4, while that in each grade of all the phases show the almost same uniformity.

The relative percentage changes in every phase of heart rate(Figure 5) increase when the cycles of sanding exercise get faster. The rate of increase is, however, less in comparison with that of Mets. The grade of 60 cycles demonstrates the increase of 12 % in Phase 2, 12 % in Phase 3 and 13 % in Phase 4 on the basis of the sitting rest position, although the rate between 15 and 30 moves, and between 30 and 60 ones in every phase increases in uniformity.

About systolic and diastolic arterial pressure(Figure 6), the mean value in each phase increases moderately. On

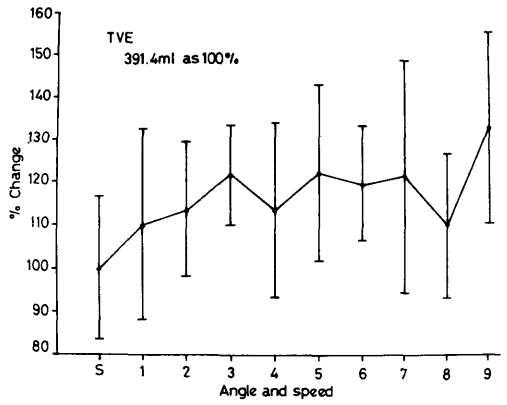


Figure 2. Variation of expiratory tidal volume (TVE).
The values from 30 to 60 cycles of Phase 2 and from 15 to 30 ones of Phase 3 decrease. The other grades get 11 to 12 % higher than the former one.

S : sitting rest.
2 : 0 degrees, 30 cycles.
4 : 15 degrees, 15 cycles.
6 : 15 degrees, 60 cycles.
8 : 30 degrees, 30 cycles.

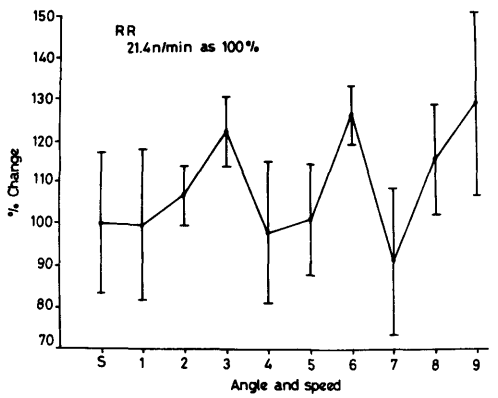


Figure 3. Variation of respiratory rate (RR).
The changes of every grade in each phase are nearly the same as in VE (Figure 1) and TVE (Figure 2).

1 : 0 degree, 15 cycles.
3 : 0 degree, 60 cycles.
5 : 15 degrees, 30 cycles.
7 : 30 degrees, 15 cycles.
9 : 30 degrees, 60 cycles.

the other hand it decreases in 30 moves of Phase 3 and the same value shows in 60 cycles of the same phase in the systolic pressure. The mean value in the last grade of Phase 2, Phase 3 and Phase 4 indicate 1.1, 1.2 and 1.2 times respectively as much as the sitting rest phase.

Pressure rate product(PRP) (Figure 7) representing systolic arterial pressure × heart rate demonstrates the equal rate of increase in each phase. The last grade in Phase 2, Phase 3 and Phase 4 get 14 %, 15 % and 16 % increase in the mean value on 100 % of the basal position. Heart rate rather than by systolic pressure is considered to exert influence upon this.

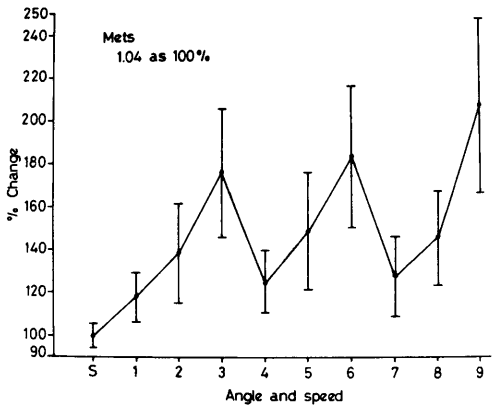


Figure 4. Variation of metabolic units (Mets).
The last grades of Phase 2, 3 and 4 indicate the increase of 17, 18 and 20 % respectively against the basal position.

S : sitting rest.
2 : 0 degrees, 30 cycles.
4 : 15 degrees, 15 cycles.
6 : 15 degrees, 60 cycles.
8 : 30 degrees, 30 cycles.

DISCUSSION

1. Ventilatory Function

In the definite angle of sanding plate, as described in RESULTS, the faster the speed of moves gets, the more VE becomes. This is true of RR, not of TVE. Since a multiplication of RR by TVE represents VE, only RR of both factors demonstrates the same proportional change as VE. It can be considered significantly that therapists should observe RR carefully in the clinic.

At an angle of 0 degree, the statistical significance shows $p<0.01$ between 30 and 60 moves, and between 15 and 60 ones. It is true of that of 15 degrees. At an angle of 30 degrees, the statistical significance indicates $p<0.05$ between 15 and 30 cycles, and $p<0.01$ between 15 and 60 ones. In

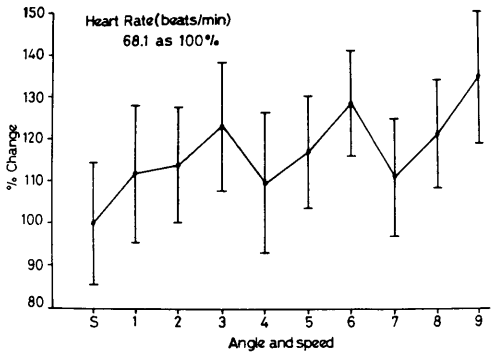


Figure 5. Variation of heart rate.
The percentage changes in every phase increase when the cycles get faster.

1 : 0 degree, 15 cycles.
3 : 0 degree, 60 cycles.
5 : 15 degrees, 30 cycles.
7 : 30 degrees, 15 cycles.
9 : 30 degrees, 60 cycles.

variation of angles in the same moves, only 60 ones between the horizontal level and 30 degrees are significant statistically ($p<0.05$).

Viewed in the above-mentioned light, the variation of angles in one hand sanding cannot be considered to exert influence upon the concerned subject's ventilation function very much, except at 30 degrees with 60 moves. The number of cycles at the fixed angle rather than angle change is of importance on one hand physical exercise. It might be thought that this exercise was carried out with one hand without any moving of her trunk, seated deeply at rest on a straight back chair.

2. Cardiometabolic Function

In proportion to increase of moves at the fixed angle, Mets increased in uniformity. In studies of sanding performed, Mets has not been focussed on. This study demonstrates, on the basis of relative rate of increase about mean value, that the statistical significance showed $p<0.01$ between 15 and 60 cycles in each phase, and $p<0.05$ and $p<0.01$ between 30 and 60 ones in Phase 2 and Phase 4, respectively. In the same moves, however, no difference

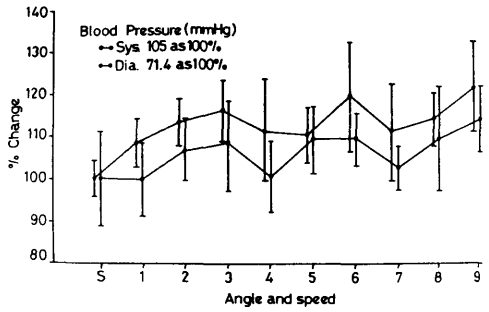


Figure 6. Variation of systolic and diastolic blood pressure.
The mean value in each phase increases moderately. In the systolic pressure, however, it decreases in 30 cycles of Phase 3 and the same value shows in 60 ones of the same phase.

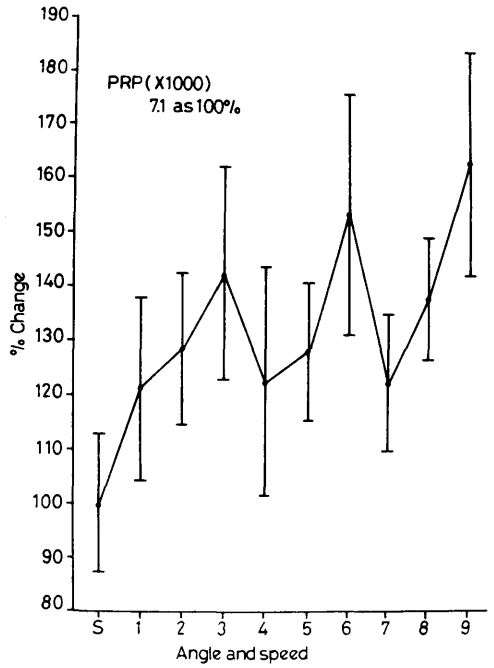


Figure 7. Variation of pressure rate product (PRP).
The last grades in Phase 2, 3 and 4 get 14 %, 15 % and 16 % increase in the mean value on 100 % of the basal position.

S : sitting rest.
1 : 0 degree, 15 cycles.
2 : 0 degrees, 30 cycles.
3 : 0 degree, 60 cycles.
4 : 15 degrees, 15 cycles.
5 : 15 degrees, 30 cycles.
6 : 15 degrees, 60 cycles.
7 : 30 degrees, 15 cycles.
8 : 30 degrees, 30 cycles.
9 : 30 degrees, 60 cycles.

between the phases was significant statistically. It can reveal that 60 cycles in each phase are effective from the viewpoint of energy.

In one hand sanding, the maximal Mets (60 moves at an angle of 30 degrees) reached no more than to 2.14 ± 0.42, equivalent to the light motion with both hands and arms or with 30-minute sitting on a chair. In case of no moving of the trunk, therefore, one hand sanding can be considered to be effective as exercise with gradual increase of load. This value of Mets does not, however, mean the heavy load for normal subjects.

PRP is represented as multiplication of heart rate by arterial systolic pressure. As variation of Mets, the former increased in uniformity in proportion to increase of moves at an angle of 0, 15 and 30 degrees.

The statistical significance represents $p < 0.05$ between 30 and 60 cycles, between 15 and 60 ones at an angle of 15 degrees, at 30 degrees between 15 and 30 moves and between 30 and 60 ones, and $p < 0.01$ between 15 and 60 ones. In comparison with the same cycles between two same angles, no difference was significant statistically.

Heart rate follows the same increase line as PRP in correspondence to increase of moves at an angle. The rate of increase in each phase is almost the same.

In systolic arterial pressure which exerts influence upon PRP, relative percentage change does not always follow a gradual increase, which demonstrates the same result as that already reported (5). The reason might, however, be enough considered to attribute to several conditions like the way to sit or to hold a sanding block. Because Mets of one hand sanding reaches no more than 1 to 2 Mets, not 4 to 5 ones like physical exercise making use of all extremities. Even a small change of conditions can be thought of exerting influence upon systolic arterial pressure. It must also be kept in mind that a previous study proved that left hand sanding influenced HR more than right hand one (7). So PRP is exerted more influence upon by HR than systolic arterial pressure.

From the point of the abovementioned, the load of cycles in each phase will physiologically induce the responses in uniformity, concerning Mets, VE and PRP. The uniformity in VE is exerted influence upon by respiratory rate and PRP is by heart rate.

In rehabilitation for patients with ischemic heart diseases and cerebral vascular accidents, considerations to combination between cycles and angle with data represented in this study can be used as index of exercise prescription regarding activities of daily living. Further study, however, suggests influences of two hand sanding and the weight change of sanding block upon metabolic and cardiopulmonary responses.

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