Differences in cardio-respiratory responses to snow shoveling and shovel performance between elderly males and females

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(Received August 29, 2005; Revised manuscript accepted November 8, 2005)

Abstract

The purpose of this study is to elucidate the differences in cardio-respiratory responses to snow shoveling and shoveling performance between elderly males and females. Eight elderly males (EM, 61–69, mean±standard errors; 64.5±1.0 yr) and five elderly females (EF, 61–75, 67.8±2.7 yr) who are habitually engaged in manual snow removal performed 10 minutes to remove 1 m width at 0.4 m depth using a snow shovel. Heart rate, volume of oxygen consumption ($\dot{V}O_2$), blood pressure, ratings of perceived exertion (RPE), and productive variables including shovel rate, shovel load and snow mass were measured. Significant differences were observed in $\dot{V}O_2$ (1.79±0.07 vs 1.20±0.06 L・min^{-1}, $p<0.001$) and metabolic equivalent (8.2±0.5 vs 6.6±0.3 Mets, $p<0.05$) between EM and EF.

Cardio-respiratory responses were somewhat higher for EM than EF, as revealed by the heart rate (158±5 vs 150±7 beats・min^{-1}, ns), systolic blood pressure (183±10 vs 178±7 mmHg, ns), diastolic blood pressure (95±4 vs 84±8 mmHg, ns) and RPE (14.9±0.7 vs 13.6±0.4, ns), respectively. The large difference in snow mass (115±18 vs 69±9 kg・min^{-1}, $p<0.001$) between EM and EF is considered to be affected by shovel load (11.4±2.0 vs 4.9±0.2 kg, $p<0.001$), not by shovel rate (10.3±2.3 vs 14.0±1.9 scoops・min^{-1}, $p<0.05$). Volume of oxygen consumption in terms of absolute value (L・min^{-1}) correlated with snow mass higher ($r=0.832$) than relative $\dot{V}O_2$ in terms of relative value ($r=0.616$).

It was concluded that snow shoveling is strenuous exercise for the elderly and that elderly females are less productive due to their smaller body size and lower physical resources.

1. Introduction

About half the areas of Japan is covered with snow during winter. Sapporo, a city in the northernmost island of Japan, has an annual cumulative snowfall of up to five meters. Such heavy snowfall occurs in cities in cold regions such as Montreal, Edmonton, Toronto, Stockholm, Minneapolis, and Harbin. Residents in Hokkaido are required to engage in the physically demanding task of snow removal every snowfall. The strenuous nature of snow shoveling has been noted previously, due to death after blizzard caused by heart attack during snow shoveling (Rogot and Padget, 1976; Glass and Zack, 1979), risk of falls from rooftops (Pipas *et al.,* 2002), and excess demand on cardiovascular function (Suda *et al.,* 1990; Sheldahl *et al.,* 1992, 1993; Smolander *et al.,* 1995; Franklin *et al.,* 1995, 1996). Heavy snow shoveling elicits myocardial infarction and aerobic demands that rival maximal treadmill and arm-ergometer testing in sedentary men (Franklin et *al.,* 1995). Moreover, since the amount of snow to be removed varies greatly depending on the weather, it is difficulty to adjust the desirable level of health, in terms of intensity, duration or frequency of exercise as recommended by the American College of Sports Medicine (ACSM, 2000). Physical resources required for snow shoveling are important determinants of independency for elderly people who have no support from their family or community.

Since snow shoveling consists of repeated exertion of the lift-and-throw motion at various shovel loads, shoveling performance as measured by the snow mass of lift-and throw is affected largely by physical resources such as gender, body size, muscular strength, muscular power, aerobic capacity, shoveling skill, mental factors, shovel design, and the nature of snow.

Reduction in muscle strength, muscular power, endurance in elderly people may be reflected in inferiority in snow shoveling performance. There are few studies on the physiological responses to manual snow removal in adult male subjects. Moreover, these papers pay little attention to the inter-relationship among physiological responses, shoveling productivity and the physical resources of the subjects.

Therefore, it is necessary to clarify the relationship between physical resources and shoveling productivity. The purpose of this study was to elucidate the physiological responses to snow shoveling in elderly males and females and to clarify the inter-relationship among physiological responses, shoveling performance and physical resources in the elderly.

2. Methods

2.1. Subjects

Eight elderly males (EM, 61–69, 64.5±1.0 yr) and 5 elderly females (EF, 61–75, 67.8±2.7 yr), living in Sapporo and the surrounding communities volunteered to be subjects in this study. None of the subjects had functional disorder or cardiovascular disease and were accustomed to manual snow clearing during their daily works. The mean (SE) height and weight of the EM were 166.1 (1.8) cm and 63.5 (2.9) kg, respectively, and those of the EF were 151.2 (2.8) cm and 52.4 (3.4) kg, respectively. All of the subjects gave informed written consent for participation in this study after receiving a complete written and verbal explanation of the proposed measures and purpose of the investigation. The ethical protocol for the study was approved by the Ethics Committee for Human Investigation of the Graduate School of Education in Hokkaido University.

2.2. Measurements

2.2.1. Physical resources

Before the experiment, physical fitness test and shovel power test were performed to assess the physical resources of the two groups. Physical fitness tests, including grip strength (muscle strength), sit-and reach (trunk flexibility), sit-ups (muscle endurance of trunk) and 6-minutes walking test (endurance) were selected as suitable because these tests were developed by the Japanese Ministry of Education, Culture, Sports, Science and Technology (2002), which were commonly performed for a wide range of the Japanese elderly population. In addition, based from the findings that back strength and leg extensor power correlated highly with shoveling throw distance (Morita *et al.,* 2002), back strength (muscle strength) and leg extensor power tests (leg power) were performed.

(1) Grip strength

Maximal grip strength was measured using a grip strength dynamometer (Takei, model T.K.K. 5401, Tokyo, Japan). Each subject held the dynamometer in line with the forearm at the level of the thigh and was instructed to squeeze with maximal force. Two attempts were made with each hand, with the best score being recorded. The scores for the right and left hands were summed to provide a single index of strength. Before the measurement, the dynamometer was calibrated by using a Dynamo-calibrator (Takei, Tokyo, Japan).

(2) Sit and reach

Each subject sat on the floor with his back and head against a wall and with legs fully extended. The subject's legs were inserted in a flex meter (Takei, model T.K.K5112, Tokyo, Japan) at a height of 30 cm. The subject grasped the edge with both hands and slid the flex meter. The arms were then stretched forward while keeping the head and back against the wall at the starting position. The subject then flexed one's trunk forward to push the flex meter as far as possible. Subjects were required to keep the flex meter at the farthest position. The test was repeated twice and the best distance was recorded.

(3) Sit-ups

Each subject lay on a mat in the supine position with knees bent at 90°. The subject's feet were held by the examiner during the test. The subject's arms were folded across the chest with hands on opposite shoulders. The subject performed a full sit-up to the upright position with their elbows touching their thighs and then returned to the down position with their scapulae in contact with the surface of the mat. The score was based on the number of times the subjects reached the frame in 30 sec.

(4) Six-minute walking distance

Endurance was assessed using a 6-minute walking distance (Guyatt *et al.,* 1985). The subjects were asked to walk over a 55 m course for 6 minutes.

(5) Back strength

Maximal back strength was measured using a back muscle dynamometer (Takei, model T.K.K.5402 Tokyo, Japan). Each subject stood on the plate of a dynamometer in the straight knee position with his upper body bent at 30° grasping the handle bar with both hands. The subject was then instructed to pull with maximal force with their knees remaining extended. Two attempts were made with the best score being recorded. Before the measurement, the dynamometer was calibrated by using a Dynamo-calibrator (Takei, Tokyo, Japan).

(6) Leg extensor power

Leg extensor power (Figure 2) was measured using an leg power system (Combi, Anaero Press 3500, Japan) in a sitting position. Each subject used a chair with a seat belt. In the starting position, the subject's feet were placed on a sliding plate with the knee angle adjusted to 90 degrees. Each subject was advised to vigorously extend one's leg opposing to braking load

Fig. 1. Measurement of cardio-respiratory responses to snow shoveling and productivity variables in elderly subject.

Fig.2. Measurement of leg extensor power.

adjusted to the same load as one's body weight. Five trials were performed at 15-s intervals, and the mean of the two highest recorded power outputs (watts) was taken as the definitive measurement (Hirano *et al.,* 1994).

(7) Shoveling throw ability

Shoveling throw ability (Morita *et al.,* 2002) was performed to evaluate the horizontal distance in snow shoveling. Each subject was asked to throw a 5 kg sandbag (30×25 cm, Sakai Medical Instrument Co. Tokyo, Japan) in males and a 4 kg sandbag (30×25 cm, Sakai Medical Instrument Co. Tokyo, Japan) using a snow shovel (1.4 kg in weight, 0.76 m in shaft length, 1344 cm^2 in the blade area, Sekisui Co.). The greater horizontal distance in two trials was recorded. The weight of the shovel load at EM was based on the findings that the optimum load of snow shoveling for adult Japanese males is 5 kg (Furukawa, 1963), that the oxygen cost of a shoveling task is lowest at a shovel load of 5 kg (Müller and Karrasch, 1956), and that the average value of shovel load during snow shoveling was about 5 kg for adult males and about 4 kg for adult females (Suda *et al.,* 1990; Sheldahl *et al.,* 1992). To assess the reliability of the shovel power test, 4-week test-retest measurements were conducted by 20 elderly males and 15 elderly females. The mean values (SE) and correlations between the first and second measurements in the shoveling throw ability were 6.6 (1.6) m vs 6.5 (1.4) m, (ns) and $r=0.92$ ($p<0.001$) in males and 4.4 (1.1) m vs 4.3 (1.0) m (ns) and $r=0.92$ ($p<0.001$) in females, respectively.

2.2.2. *Productivity variables*

Snow shoveling performance was determined by the amount of snow (snow mass) thrown onto a vinyl sheet over a period of 4 minutes and was expressed as $kg \cdot min^{-1}$. The shovel rate ($scoop \cdot min^{-1}$) was expressed as the number of scoops per minute. The shovel load (kg) was expressed as the weight of snow per scoop of shoveling (shovel load = snow mass ÷ shovel rate).

2.2.3. *Cardio-respiratory responses*

Cardio-respiratory variables ($\dot{V}O_2$, $\dot{V}CO_2$, and minute ventilation: $\dot{V}_E$), heart rate, blood pressure, and ratings of perceived exertion (Borg, 1970) were measured at rest, during 10 minutes of snow shoveling, and during the recovery period. A portable expiratory gas analyzer (VO2000, Medical Graphics Co., Minnesota, USA) was used to measure respiratory variables. Oxygen consumption ($\dot{V}O_2$) during snow shoveling is expressed here as absolute $\dot{V}O_2$ ($L \cdot min^{-1}$), relative $\dot{V}O_2$ ($mL \cdot kg \cdot min^{-1}$, = absolute $\dot{V}O_2$ /body weight) and metabolic equivalents (Mets = relative $\dot{V}O_2$/3.5). One metabolic equivalent equals 3.5 $mL \cdot kg \cdot min^{-1}$. For example, oxygen consumption during level walking at 80 m · min is estimated as 12 $mL \cdot kg \cdot min^{-1}$ in terms of relative $\dot{V}O_2$. This value corresponds to 3.5 Mets (=12/3.5) in terms of metabolic equivalent and, in the case of a subject with a body weight of 60 kg, corresponds to 0.72 $L \cdot min^{-1}$ in terms of absolute $\dot{V}O_2$ ($=60\times12=720$ mL/min $=0.72$ $L \cdot min^{-1}$). (Ainsworth, 2000).

Heart rate was recorded from an electrocardiogram (ECG) using an ambulatory ECG recorder (Holter Co., DMC-3252). Ratings of perceived exertion (RPE) were assessed using the Borg 20-point scale (Borg, 1970) Blood pressure measurement was performed at rest and immediately after work using an automatic sphygmomanometer (Omron, HEM714C, Japan).

2.2.4. *Experimental condition*

Subjects wore the same clothing as their usual wear and rubber boots for snow removal in their home. To assess the physiological responses to snow shoveling and productivity variables, subjects were instructed to repetitively lift-throw snow onto a vinyl sheet from 0.4 m depth and 1 m width of snow layer cleared at a self-paced rate using a lightweight alumi-

Table 1. Physical characteristics and fitness of the subjects.

	EM (n=8)	EF (n=5)	p-value
Age (years)	64.5±1.0	67.8±2.7	0.186
Height (cm)	166.1±1.8	151.2±2.8	0.000
Weight (kg)	63.4±2.9	52.4±3.4	0.040
Grip strength (kg)	39.3±1.2	23.5±1.9	0.000
Sit-and-reach (cm)	36.3±2.3	38.8±3.8	0.557
Sit-ups (times)	16.1±2.2	12.2±0.6	0.184
Back strength (kg)	129.3±11.3	82.2±5.3	0.000
Leg extension power (watt)	1191±60	659±100	0.000
6-minutes walk distance (m)	708±19	620±18	0.011
Shoveling throw ability (m)	7.3±0.5	4.7±0.4	0.000*

Values are means (S.E). .* Shovel load at shoveling throw ability were 5 kg in man and 4 kg in women.

Table 2. Comparison in cardio-respiratory responses during snow shoveling between EM and EF.

	EM (n=8)	EF (n=5)	p-value
RPE	14.9±0.7	13.6±0.4	0.189
Heart rate (beats・min^{-1})	157.8±5.0	149.9±6.5	0.356
$\dot{V}O_2$ (L・min^{-1})	1.79±0.1	1.20±0.1	0.000
$\dot{V}O_2$ (mL・kg・min^{-1})	28.6±1.6	23.0±1.0	0.029
Mets	8.2±0.5	6.6±0.3	0.029
Systolic B.P. (mmHg)	183.4±9.6	178.0±6.7	0.696
Diastolic B.P. (mmHg)	94.9±3.7	83.6±7.8	0.167

Values are means (S.E).

num shovel (1.2 kg, Sekisui Co. Tokyo, Japan) for a period of 10 minutes. Before the work periods, the hard crust of the snow surface was broken up and homogenized. The density of snow was measured with a snow density sampler standardized by the Japanese Society of Snow and Ice (1991). Mean (±SE) snow density was 0.32±0.1 g・cm^3. During the test days, air temperature and humidity varied from −2 to +4℃ and from 22 to 68%, respectively.

2.2.5. *Statistical analysis*

Results are expressed as means±standard errors (m±SE). A student's *t*-test was used to determine any significant difference between sexes in the subjects' physical characteristics and other measurement values. Relationships between variables of interest were determined using Pearson's correlation coefficient. Differences were considered significant if $p < 0.05$.

3. Results

3.1. *Physical resources*

Significant differences were observed in height, weight, grip strength, back strength, 6-minutes walking distance and leg extensor power between EM and EF as shown in Table 1. Despite the fact that the shovel load was 1 kg lower in EF than EM, shoveling throw ability was significantly lower in EF than EM.

3.2. *Cardio-respiratory responses*

Table 2 shows the mean value of cardio-respiratory responses to snow shoveling. At rest, systolic blood pressure were 140±5 vs 140±10 mmHg (ns) and diastolic blood pressure were 85±5 vs 85±4 mmHg (ns) respectively. Cardio-respiratory responses were somewhat higher for EM than EF considering the fact that the heart rate (158±5 vs 150±7 beats/min, ns), systolic blood pressure (183±10 vs 178±7 mmHg, ns), diastolic blood pressure (95±4 vs 84±8 mmHg, ns) and RPE (14.9±0.7 vs 13.6±0.4, ns) were slightly higher in EM than in EF. Heart rate during snow shoveling from the start to 7 minutes revealed similar trend between males and females. Male subjects tend to exert higher pace at final phase of exercise while female subjects adjust their exertion somewhat lower. These differences are considered to reflect on delay in recovery period in male subjects as shown in Fig. 3.

Oxygen consumption ($\dot{V}O_2$) in terms of absolute value (1.79±0.07 vs 1.20±0.06 L・min^{-1}, $p < 0.001$), relative value (28.6±1.6 vs 23.0±1.0 mL・kg・min^{-1}, $p < 0.05$) and metabolic equivalent (8.2±0.5 vs 6.6±0.3 Mets, $p < 0.05$) were significantly higher in EM than MF.

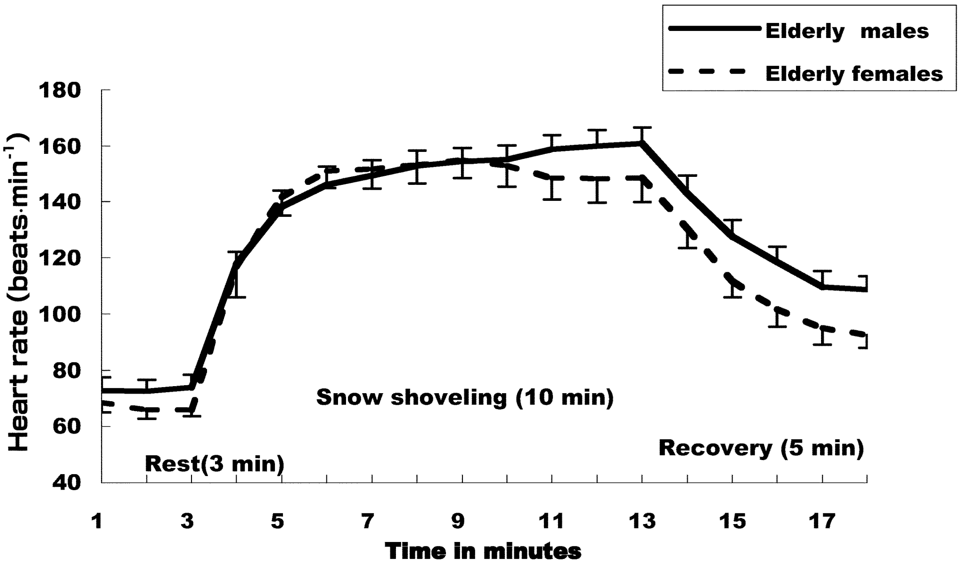

Fig. 3. Trendgraph of the heart rate at rest, during snow shoveling and recovery in elderly males (N=8) and females (N=5). Value are mean±SEE.

Table 3. Comparisons in productivity variables of snow shoveling between EM and EF.

	EM (n=8)	EF (n=5)	*p*-value
Shovel rate (scoops・min^{-1})	10.6±0.8	14.1±0.9	0.018
Shovel load (kg)	11.0±0.6	4.9±0.1	0.000
Snow mass (kg・min^{-1})	114.7±7.0	69.2±5.0	0.000

Values are means (S.E).

3.3. *Productivity variables*

Table 3 shows the mean value of the shovel rate, shovel load and snow mass. There were large differences in shovel load (11.1±0.6 vs 4.9±0.1kg, $p<0.001$) and snow mass (114.7±6.8 vs 69.2±4.6 kg・min^{-1}, $p<0.001$) between EM and EF. On the other hand, the shovel rate was significantly higher in EF than EM.

As illustrated in Figure 4, remarkable differences were observed both in snow mass and oxygen consumption between EM and EF. Oxygen consumption during snow shoveling increased proportionally with increase in snow mass.

Table 4 presents correlation coefficients between the variables of physical resources as explanation variables and snow mass as an objective variable. Sit-and-reach to assess trunk flexibility shows no relationship to snow mass. Variables in body dimensions, although showing significant correlation, were relatively lower compared to the physical fitness parameters. Considering the fact that the shovel load in the shoveling throw ability is heavier in males (5 kg) than females (4 kg), the shoveling throw ability is thought to be a good predictor for snow shoveling performance.

Table 4. Correlation coefficients between variables of physical resources and snow mass in overall subjects (N=13).

	r	*p*-value
Height (cm)	0.525	0.033
Weight (kg)	0.499	0.041
Grip strength	0.799	0.005
Sit-and-reach	−0.227	0.772
Sit-ups	0.761	0.001
Back strength	0.779	0.008
Shoveling throw ability	0.823	0.000
$\dot{V}O_2$ during exercise (L・min^{-1})	0.832	0.000
$\dot{V}O_2$ during exercise (mL・kg・min^{-1})	0.613	0.013
6-minutes walk distance	0.618	0.012
Leg extensor power	0.691	0.006

4. Discussion

The major findings of this study are: 1) elderly males performed significantly higher shovel productivity expressed as lift-and-throw snow mass (kg・min^{-1}) than elderly females under slightly higher cardio-respiratory responses; 2) the lower value of snow mass in elderly females is considered to be due to the

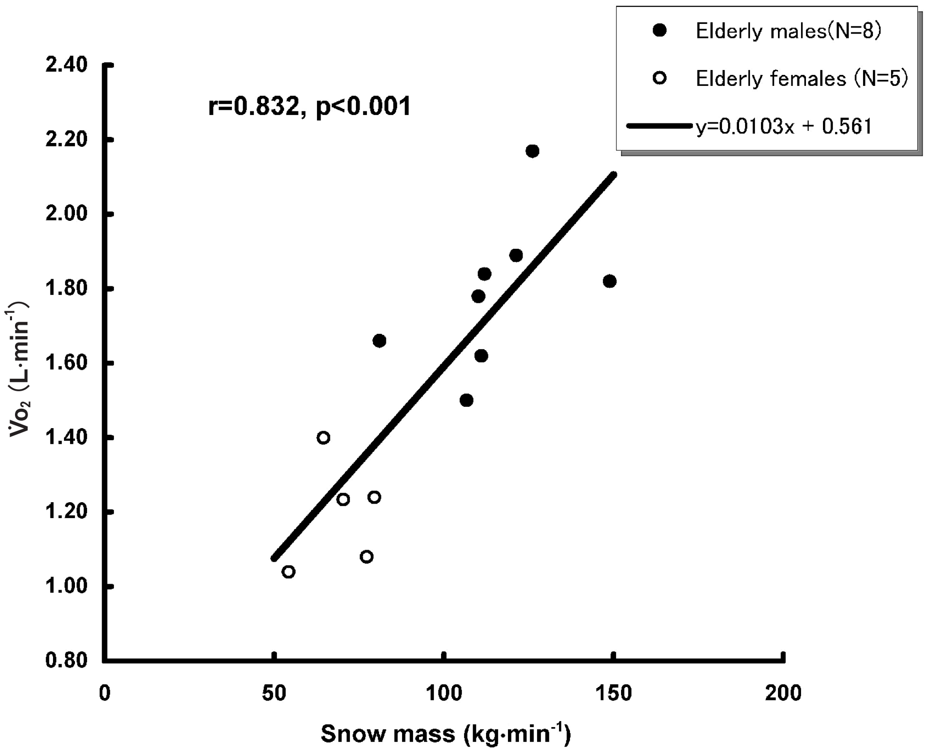

Fig. 4. Snow mass (kg・min^{-1}, x) and $\dot{V}O_2$ (L・min^{-1}, y) in elderly males and elderly females during snow shoveling.

disadvantage in smaller body size and lower physical fitness; 3) VO_2 increased proportionally with snow mass, and 4) differences in $\dot{V}O_2$ (24%) in terms of relative value (mL・kg・min^{-1}) or metabolic equivalent (24%) between males and females were enlarged when $\dot{V}O_2$ was expressed as absolute value (49%) and reflected on the large difference in snow mass (66%).

4.1. *Cardio-respiratory responses to snow shoveling*

The strenuous nature of snow shoveling are well documented by previous studies (Suda *et. al.* 1990; Sheldahl *et al.* 1992, 1993; Franklin *et al.* 1995; Smolander *et al.* 1995). In this study, mean values in oxygen consumption during snow shoveling expressed as an absolute value in $\dot{V}O_2$ (1.79±0.07 vs 1.20±0.06 L・min^{-1}), relative value (28.6±1.6 vs 23.0±1.0 mL・min^{-1}), metabolic equivalent (8.2±0.5 vs 6.6±0.3 Mets) were significantly higher in EM than those in EF. As presented in Table 5, exercise intensity in terms of metabolic equivalent (8.2 Mets) of EM in this study revealed lower than that during snow removal using a snow pusher by middle-aged males (9.5 Mets) reported by Smolander *et al.* (1995) but higher than those during snow shoveling performed by middle aged males (Sheldahl *et al.*, 1992; Franklin *et al.*, 1995), patients of coronary artery disease (Sheldahl *et al.*, 1993), middle-aged females (Sheldahl *et al.*, 1993) or elderly males (Suda *et al.*, 1990; Sheldahl *et al.*, 1993). This tendency was also observed in EF in this study. Oxygen consumption in terms of metabolic equivalent in EF was higher than that during snow shoveling performed by female subjects reported by Sheldahl *et al.* (1993).

At any rate, both in EM and EF, exercise intensity in this study were classified as "vigorous activity," defined as greater than 6 Mets, in accordance with ACSM (2000) guidelines. Heart rate during steady state reached almost HR_{max} (97% in males and 93% in females) of the estimated value derived from new formula ($HR_{max}=208-(0.7\times age)$) proposed by Tanaka *et al.* (2001). Considering that there exist large variation in maximum heart rate among older population and that RPE were not extremely high, averaging 14.9 (correspond to "hard ") in EM and 13.6 (in the midst of "somewhat hard" and "hard") in EF, the snow shoveling demand highly on cardiovascular function as reported by Franklin *et al.* (1996).

Oxygen consumption during snow shoveling increased proportionally with increase in snow mass as shown in Figure 3. These data are consistent with a previous study on elderly males showing that oxygen consumption correlate significantly ($r=0.768$, N=13, $p<0.01$) (Suda *et al.*, 1990) with snow mass. Therefore, it is obvious that aerobic power may be one of the determinants of snow shoveling performance. Oxygen consumption during shoveling exceeded 8 Mets in elderly males and exceeded 6 Mets in elderly females. These intensities correspond to 80%$\dot{V}O_2$max of average values for Japanese males and females in their 60's (Physical fitness laboratory Tokyo Metropolitan University, 2000). Therefore, snow shoveling requires high oxygen consumption and demands on cardiovascular function as pointed out from previous studies (Suda *et al.,* 1990; Sheldahl *et al.,* 1992, 1993; Smolander *et al.,* 1995; Franklin *et al.,* 1995, 1996), considering the fact that the duration of work last for occasionally several hours after a heavy snowfall. Such strenuous exercise is rare in daily physical activities for the elderly in developed countries.

4.2. *Relationship between physical resources and shovel productivity*

The present study, to our knowledge, is the first to provide the inter-relationship among physical resources, cardio-respiratory responses and shoveling performance in snow shoveling in elderly men and women. Although the sample size was limited in small, physical fitness such as muscle strength, muscle power and endurance correlated significantly with snow shoveling performance in terms of snow mass. Suda *et al.* (2005) pointed out that muscle strength and leg extensor power are essential determinants for elderly people living in snowy regions since muscle strength, represented by grip strength and back strength and leg extensor power correlated significantly with shoveling throw ability.

The higher correlation coefficient between shoveling throw ability and snow mass shows why the shoveling throw ability test was developed to assess the functional mobility for people in snowy regions with special relation to snow shoveling and involves various factors such as body size, muscle strength, power and throwing skill of shovel load.

Figure 4 shows the existence of a different pattern in shoveling strategy between males and females. Female subjects tend to maintain a certain rate of scooping to compensate their disadvantage in lower shovel load than male subjects. On the other hand, the current study suggests that there are other factors that influence shoveling performance. The data included the cases showing that subjects of higher strength, power, endurance or shovel power did not attain high shovel performance both EM and EF.

The absolute $\dot{V}O_2$ ($L \cdot min^{-1}$) correlated highly ($r=0.832$) than with snow mass than the relative $\dot{V}O_2$ ($mL \cdot kg \cdot min^{-1}$) ($r=0.613$). Among various daily physical activities, oxygen consumption of the locomotive type of exercises (weight-bearing) such as walking, running, cycling, stair climbing, are expressed as relative $\dot{V}O_2$, to cancel the effect of body weight dividing $\dot{V}O_2$ by body weight) and usually relative $\dot{V}O_2$ is considered to be the most important factor as "health-related fitness" or "sport-related fitness". This tendency was also observed with young subjects (Morita *et al.,* in press).

Although the importance of relative VO_2 is well documented, the present investigation elucidated the importance of absolute $\dot{V}O_2$ to attain higher shoveling performance. This characteristic is explained by the difference in the type of exercise, that is to say, in case of snow shoveling, a large proportion of energy is allocated to external work to lift-and-throw shovel load and the energy for locomotion is small. This finding is necessary to remind people living in snowy region of the disadvantage in snow shoveling for older women who are smaller in body size and lower in muscle strength and power. Nevertheless, in Japanese, many elderly people who are unfit or having health problem are forced to engage in demanding snow removal with no support from family or neighbors.

4.3. *Required level of fitness for the maintenance of independency in snowy regions*

A positive significant correlation ($r=0.765$, $p>0.01$) was found between the shovel load and the snow mass. These results are consistent with previous findings (Suda *et al.,* 1990). Although this strategy may be advantageous to attain higher performance for elderly people, may increase the risk of heart attack induced by increase of systolic blood pressure triggered by Valsalva maneuver of isometric contraction and exposure to cold environment as pointed out by Franklin *et al.* (1995).

Shephard (1987) had proposed that an oxygen uptake of $15\,mL \cdot kg^{-1} \cdot min^{-1}$ (4.3 Mets) was the threshold for the activities of daily living. Paterson *et al.* (1999) also reported that the minimum level of aerobic power compatible with an independent life at age 85 yr was approximately $18\,mL \cdot kg^{-1} \cdot min^{-1}$ (5.1 Mets) in men and $15\,mL \cdot kg^{-1} \cdot min^{-1}$ (4.3 Mets) in women. These values are assumed to require to perform a certain minutes of usual task such as level walking at $80\,m \cdot min^{-1}$ (3.5 Mets). However, it is obvious that these criterions do not satisfy the independency of the elderly people living in snowy regions who have no support for removing snow due to the fact that oxygen consumption of snow shoveling by women of 50^{th} the amount to 5.2 Mets during snow shoveling as pointed out by Sheldahl (1992) and that by women of 60^{th} averaged 6.6 Mets in the present study. Even if unfit women try to the adjust intensity to their physical resources by lowering the shovel load and shovel rate, this strategy requires prolonged work time under cold temperature.

In this study, relationships between shovel power and snow mass remain unclear since higher performance was not attained by heavier shovel load despite the significant correlation ($r=0.849$, $p<0.01$) being observed by overall subjects, the highest performer was not higher in shoveling throw ability both in EM and EF. Further study is needed to elucidate which factor in physical resources is important for higher performance in snow shoveling and to distinguish the characteristics.

Table 5. Intensities of snow removal reported by previous studies.

Authors		Type of snow removal	Subjects	Age of subjects	Heart rate (beats・min^{-1})	Intensity (Mets)
Franklin *et al*.	1995	Snow shoveling	10M	32	175	5.7
Franklin *et al*.	1995	Snow Blower	10M	32	124	2.4
Suda *et al*.	1990	Snow shoveling	14M	74	126	5.5
Sheldahl *et al*.	1992	Snow shoveling	12M	40	116	7.2
Sheldahl *et al*.	1992	Snow shoveling	13M	61	114	6.4
Smolander *et al*.	1995	Snow pusher	9M	43	142	9.5
Sheldahl *et al*.	1993	Snow shoveling	12F	>50	85%peakHR	5.2
Sheldahl *et al*.	1993	Snow blower	12F	>50	78%peakHR	5.2
Sheldahl *et al*.	1993	Snow shoveling	CAD8F	>50	81%peakHR	5.1
Sheldahl *et al*.	1993	Snow blower	CAD8F	>50	77%peakHR	4.6

CAD : Coronary artery disease.

Another limitation in the present study is that, to perform the experiment safely, subjects recruited for the studies may be biased in favor of the more fit individuals than representatives of normal aging and excluded subjects who have any cardio-vascular disorder or motor function since the snow shoveling demand on cardio-vascular function and danger to persons with cardiac risk factors as pointed out by Smolander *et al.* (1995) or Franklin *et al.* (1995).

As reported by Franklin *et al.* (1996), during snow shoveling in 10 sedentary men (mean age±SD, 32.4±2.1 years), at a rate at which they removed snow at home, despite the fact that oxygen consumption was 39% lower (5.7 Mets) than these during maximal treadmill testing (9.3 Mets; $p<0.003$), the peak heart rate, blood pressure, and perceived exertion increased high level, averaging 175 beats・min^{-1}, 198 mmHg, and 16.7 (very hard effort), respectively. These values were comparable to or higher than the maximum values achieved by the same subjects during maximal treadmill testing. Although perceived exertion in this study were lower both in males and females than those in Franklin et al., the same tendency of increase in higher heart rate were observed in this study. Therefore, warning signs of over exertion may be deceptively camouflaged by the moderate aerobic requirement (Mets) or perceived exertion.

5. Conclusion

The main findings obtained from the measurements of cardio-respiratory responses to 10 minutes of snow shoveling and shoveling productivity in 13 healthy elderly subjects (8 males and 5 females) were as follows:

- There was no significant difference between EM and EF in cardiovascular function. The heart rate during a steady state of exercise reached almost the same level as the estimated nearly maximum value both in EM (158±5 beats・min^{-1}) and EF (150±7 beats・min^{-1}). Blood pressure immediately after exercise was slightly higher in EM than in EF both for systolic blood pressure (183±10 vs. 178±7 mmHg, ns) and diastolic blood pressure (95 ±4 vs. 84±8 mmHg, ns)
- Oxygen consumption in terms of the relative value was 24% higher in EM than MF (28.6±1.6 vs. 23.0±1.0 mL・kg・min^{-1}, $p<0.01$). The difference was increased when oxygen consumption was expressed as absolute VO_2 (1.79±0.07 vs. 1.20 ±0.06 L・min^{-1}, +49%, $p<0.001$). Oxygen consumption in terms of absolute VO_2 correlates with snow mass higher ($r=0.832$, $p<0.001$) than relative VO_2 ($r=0.613$, $p<0.05$). These relations suggest that performance in snow shoveling is affected not only by aerobic power, but also by body size.
- There was a large difference in snow mass, expressed as the weight of lift-and-throw snow per minute between EM and EF (115±18 vs. 69±9 kg・min^{-1}, $p<0.001$); the difference was due to shovel load (11.4±2.0 vs. 4.9±0.4 kg/scoop, $p<0.001$) not shovel rate (10.3±2.3 vs. 14.0±1.9 scoops・min^{-1}, $p<0.05$). These characteristics explain how snow shoveling is demanding work for the elderly. Elderly female are disadvantage for shovel performance due to smaller body size, lower muscle strength, muscle power and aerobic power.

Acknowledgment

We would like to thank Professor Eiji Akitaya for the help in measuring the density of snow. This study was supported in part by a Grant in Aid for Scientific Research from the Japanese Ministry of Education, Science, Culture, Sport and Technology (2001–2003).

References

Ainsworth, B.E., Haskell, W.E., Whit, M.C., Irwin, M.L., Swarz, A.M., Strath, S.J., O'Brien, W.L., Bassett, D.R. Jr., Schmiz, K.H., Emplaincort, P.O., Jacobs, D.R and Leon, A.S. (2000): Compendium of physical activities: an update of activity coded and MET intensities. Medicine and Science in Sports and Exercise, **32**, Supplement, S498–504.

American College of Sports Medicine (2000): ACSM's Guidelines for Exercise Testing and Prescription, sixth ed. Lippincott Wiiliams and Wilkins, Philadelphia, 147–149.

Borg, G. (1970): Perceived exertion as an indicator of somatic stress. Scand J. Rehabil. Med. **2**, 92–98.

Franklin, B.A., Hogan, P., Bonzeim, K. Bakalyar, D., Terren, E., Gordon, S. and Timmis, G.C. (1995): Cardiac demands of heavy snow shoveling. J.A.M.A., **15**, 880–882.

Franklin, B.A., Bonzheim, K,. Gordon, S. and Timmis, G.C. (1996): Snow Shoveling: A trigger for Acute Myocardial Infarction and Sudden Coronary Death. The American Journal of Cardiology. **77**, 855–858.

Furukawa, I. (1963): A study on the motion of snow shoveling. Journal of the Japanese Society of Snow and Ice. **25**, 3–7 (in Japanese).

Glass, R.I. and Zack, M.M. (1979): Increase in deaths from ischemic heart disease after blizzards. The Lancet, **3**, 485–487.

Guyatt, G.H., Braincon, S. and Porel, J. (1985): The 6-minutes walk: a new measure of exercise capacity in patients with chronic heart failure. Canadian Medical Association Journal, **132**, 919–923.

Hirano, Y., Noguchi, A. and Miyashita, M. (1994): The explosive leg extensor power output and Its evaluation with the function of sex and age. Japanese Journal of Physical Fitness and Sports Medicine. **43**, 113–120, (in Japanese).

Japanese Society of Snow and Ice (1991): Measurement of snow and Ice. Hokkaido University Publisher, 29–45 (in Japanese).

Morita I., Yamaguchi A., Suda T.（2002）: Relationship between and strength, power and snow shoveling. Journal of the Japanese Society of Snow and Ice, **64**, 631–639 (in Japanese).

Morita I., Yamaguchi A., Yoshinari T., Hayashi M., Suda T.（2005）: Cardio-respiratory response to snow shoveling and shovel performance in young males. Journal of the Japanese Society of Snow and Ice, **68**, 3–13 , (in Japanese).

Müller, E.A. and Karrasch, K. (1956): Die grosste Dauerleistung beim Schaufeln. Internationale Zeitschrift fur angewandte Physiologie einschliesslich Arbeitphysiologie. **16**, 318–324.

Paterson, D.H., Cunningham, D.A., Kova, J.J. and St Croix, C. M.(1999): Aerobic fitness in a population of independently living men and women aged 55–86 years. Med. Sci. Sports Exerc., **31**, 1813–1820.

Pipas, L., Schaefer, N., Brown, L. (2002): Falls From Rooftops After Heavy Snowfalls: The Risks of Snow Clearing Activities. American Journal of Emergency, 20, 635–637.

Physical Fitness Laboratory Tokyo Metropolitan University (2001): Physical fitness standards of Japanese people (in Japanese). Humaidoh,320–326.

Rogot, E. and Padgett, J., (1976): Association of Coronary and Stroke Mortality with Temperature and Snowfall in Selected Areas of the United States, 1962–1966. Am. J. Epidm. **103**, 565–572.

Sheldahl, L.M., Wilke, N.A., Dougherty, S.M., Levandoski, S. G., Hoffman, M.D. and Tristiani, F.E. (1992): Effects of Age and Coronary Artery Disease on Response to Snow Shoveling. JACC, **20**, 1111–1117.

Sheldahl, L.M., Wilke, N.A., Dougherty, S.M. and Tristiani F. E (1993): Responses of women to snow shoveling and snow blowing. Circulation, **88**, 610.

Shephard, R.J. (1987): Physical Activity and Aging. Second edition , Croom Helm, London and Sidney, 86–92.

Smolander, J., Louhevaara, V., Ahonen, E., Polari, J. and Klen, T. (1995): Energy expenditure and clearing snow: a comparison of shovel and snow pusher. Ergonomics, **38**, 794–753.

Suda, T., Nakagawa, K., Miyake, S., Sasaki, T., and Katoh, M. (1990): Physiological responses to snow shoveling observed in aged men. Ed. Kaneko, Fitness for the Aged, Disabled and Industrial Worker. Human Kinetics, Illinois, 75–78.

Suda, T., Asao, H. and Morita, I. (2005): Differences in the Relationships between Physical Resources and Vital Functions of College Students and Elderly People Living in a Snowy Region. Scientific Proceedingsfrom the 6th World Congress on Aging and Physical Activity. Journal of Aging and Physical Activity, 82–86.

Tanaka, H., Monahan, K.D. and Seals, D.R. (2001) Age-related maximal heart rate revised. J. Am. Coll. Cardiol. **37** (1): 153–156.

The Sports and Youth Bureau, The Ministry of Education, Culture, Sports, Science, and Technology (2002): Statistical report on physical fitness and motor fitness performance in Japanese (in Japanese), 43–50.