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# Snow removal maintained a high level of physical activity in patients undergoing hemodialysis in heavy snowfall areas



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## Abstract

**Background:** Physical activity is an essential parameter associated with the prognosis of hemodialysis patients. Physical activity has regional characteristics; for example, snow removal is imperative in snowbelts during the winter. This study investigated the effects of removing snow on the physical activity levels of hemodialysis patients living in a snowbelt.

**Methods:** This study retrospectively examined 28 patients who underwent hemodialysis (age  $69.6 \pm 15.4$  years, 19 males) in Uonuma Kikan Hospital between December 2019 and March 2020. Physical activity was assessed using the International Physical Activity Questionnaire. Patients were divided into a snow remover group and a non-snow remover group. We examined whether there were differences in physical or mental functioning and physical activity between the two groups. We also investigated the factors that influence high levels of physical activity among hemodialysis patients using multivariate linear regression analysis.

**Results:** The snow remover group had significantly greater grip strength, higher sit-to-stand test scores and gait speed, and a lower prevalence of frailty than the non-snow remover group. The level of physical activity was also significantly higher in the snow remover group. One of the patients in the snow remover group was frail. The univariate linear regression analysis showed that physical activity was related to age, grip strength, sit-to-stand test score, gait speed, and snow removal. In the multivariate linear regression analysis, snow removal and grip strength were significantly associated with a high level of physical activity.

**Conclusions:** Among hemodialysis patients living in a snowbelt, the snow remover group had significantly better physical functioning and a higher level of physical activity.

**Keywords:** Hemodialysis, Physical activity, Snow removal, Heavy snowfall area

## Introduction

Despite advances in dialysis technology and disease management, the mortality rate of hemodialysis patients remains high [1]. There is a close relationship between mortality and low physical activity among hemodialysis

patients [2], and increasing physical activity leads to an improved prognosis [1]. A previous study reported that hemodialysis patients engage in less physical activity than healthy subjects [3], and interventions to increase physical activity are needed.

It has been reported that parameters of physical functioning such as muscle strength [4] and muscle mass [5] are related to physical activity. Physical activity also has regional characteristics [6]. For example, in snowbelts, snow removal is an essential physical activity during the

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winter. However, to our knowledge, no studies have examined the effects of snow removal on the level of physical activity among hemodialysis patients.

The Uonuma area in Niigata Prefecture is one of Japan's primary snowbelts and has been designated a particularly heavy snowfall area by the Act on Special Measures Concerning Heavy Snowfall Areas [7]. The annual average amount of snow exceeds 1.3 m [8]. Moreover, depopulation is occurring in this area, and the number of individuals living alone is increasing. Many people have to remove snow by themselves, including some dialysis patients. In this context, the purpose of this study was to examine the effect of snow removal on hemodialysis patients' level of physical activity in a snowbelt. We believe that this study could provide information that could be useful for managing the physical activity of hemodialysis patients in snowbelts.

## Methods

### Study subjects

This study retrospectively enrolled 33 patients who underwent hemodialysis from December 2019 to March 2020 in Uonuma Kikan Hospital. All subjects lived in the Uonuma area in Niigata Prefecture (Minami Uonuma City, Uonuma City). Patients who had unstable arrhythmia ( $n = 0$ ), unstable hypertension ( $n = 0$ ), or were unable to walk ( $n = 5$ ) were excluded. A total of 28 patients were eligible for study enrollment. After registration, the same examiner evaluated the participants' characteristics. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Uonuma Kikan Hospital (no. 30-056). Participants were given the opportunity to opt out of this study.

### Clinical characteristics

The participants' age, sex, time on dialysis, body mass index (BMI), and family structure were collected from the medical records. In addition, the underlying etiology of dialysis, comorbidities, and levels of hemoglobin, serum albumin, and C-reactive protein were also collected from the medical records.

### Snow removal activity

Based on a previous study [9], participants were asked whether they removed snow during the winter. Those who answered "yes" were defined as "snow removers." The frequency, duration, and area of snow removal were not specified. We asked about the removal of snow within the last year to limit the period.

### Evaluations of physical and mental functioning

The participants' grip strength, sit-to-stand test (STS) score, and gait speed were evaluated as recommended in

the renal rehabilitation guidelines [10] and described in previous studies [11, 12]. The STS score is the time needed to stand up from the seated position five times and is included in the short physical performance battery [12]. Gait speed was defined as the speed at which each participant felt comfortable walking. A multifrequency bioelectrical impedance device (InBody S10, Biospace, Japan) was used to estimate muscle mass. The skeletal muscle index (SMI) was calculated as follows:  $SMI = \text{lean muscle mass}/\text{height}^2$  [11]. The estimated muscle mass was measured within 30 min after dialysis. Frailty was evaluated using the J-CHS Index [13]. Frailty was diagnosed if a participant met three or more of the following criteria: weight loss, weakness, exhaustion, slowness, and low physical activity level. The Patient Health Questionnaire (PHQ)-9 was used to screen for depression [14].

### Physical activity

We used the International Physical Activity Questionnaire (IPAQ)—Short Form to evaluate physical activity. The IPAQ has been recognized worldwide for its reliability and validity [15]. The usefulness of this questionnaire for the evaluation of physical activity in Japanese populations has been reported [16]. The amounts of physical activity performed that was categorized as high intensity, moderate intensity, and mild intensity were calculated based on the methods described in a previous study [16]. The sum of patient-reported activities according to the IPAQ was defined as the total physical activity level, and the metabolic equivalent of task (MET) score per week (MET-min/week) was calculated. The sum of the time spent engaged in moderate- and high-intensity activity was defined as moderate-to-vigorous intensity physical activity (MVPA).

### Statistical analysis

A chi-squared test was used to compare categorical variables between the snow remover group and the non-snow remover group. An unpaired  $t$  test was used to analyze continuous variables. A univariate linear regression analysis was performed with physical activity as the dependent variable. The variables that were significant in the univariate regression analysis were used as independent variables in a multivariate linear regression analysis. The presence or absence of snow removal was used as a dummy variable. All statistical tests were performed using SPSS version 21.0 (IBM Corp., Japan).  $P$  values less than 0.05 were considered to indicate statistical significance.

## Results

We collected the temperature, wind speed, precipitation, and snowfall information in the Uonuma area from December 2019 to March 2020 (Table 1). The

**Table 1** Meteorological data for the Uonuma area in winter

Average temperature (°C)	Average precipitation (mm)	Average wind velocity (m/s)	Average snowfall (cm)
2.5±3.2	5.4±6.3	2.1±0.9	6.1±5.6

This data is the average from December 2019 to March 2020. Values are means ± standard deviation

information is posted on the Japan Meteorological Agency Website [17]. During this period, there was less snow than usual for the time of year.

#### Patient characteristics

Table 2 shows the clinical characteristics of the patients. After applying the exclusion criteria, 28 patients were included. Ten patients performed snow removal. There were no significant differences between the two groups in age, sex, BMI, time on dialysis, or levels of hemoglobin, serum albumin, or C-reactive protein. Two patients were living alone, and they removed the snow by themselves.

#### Physical and mental functioning

Table 3 shows the physical and mental functioning of the two groups. The snow remover group had significantly greater grip strength and higher STS score and gait speed ( $p = 0.028$ ,  $p = 0.015$ , and  $p = 0.038$ , respectively). Among all the patients, 42.9% were frail, and significantly fewer patients were frail in the snow remover group than in the non-snow remover group ( $p = 0.011$ ). One of the patients who performed snow removal was frail, and he lived alone. There was no significant difference in the SMI and PHQ-9 scores between the two groups.

#### Effect of each index on physical activity

Table 4 shows the results of the univariate and multivariate linear regression analysis for total physical activity. The univariate linear regression analysis showed that physical activity was related to age, grip strength, STS score, gait speed, and snow removal ( $p = 0.003$ ,  $p = 0.016$ ,  $p = 0.024$ ,  $p = 0.044$ , and  $p = 0.001$ , respectively). For the variables that were significant in the univariate linear regression analysis, the correlation coefficients were calculated to confirm the multicollinearity. As a result, strong correlations were found between grip strength and STS score ( $r = -0.821$ ,  $p < 0.001$ ), between grip strength and gait speed ( $r = 0.809$ ,  $p < 0.001$ ), and between STS score and gait speed ( $r = -0.827$ ,  $p < 0.001$ ). Therefore, we used grip strength as an independent variable, and grip strength was reported in a previous study as being related to physical activity [4]. The STS score and gait speed were excluded. The multivariate linear regression analysis was performed using age, grip strength, and snow removal as independent variables. Physical activity was the dependent variable. Grip strength and snow removal were associated with physical activity ( $p = 0.035$  and  $p = 0.002$ , respectively). That is,

patients with stronger grip strength who also performed snow removal had a higher level of physical activity. However, the adjusted  $R^2$  value was 0.41. Physical activity may be affected by other factors. Table 5 shows the results of the univariate and multivariate linear regression analyses for MVPA. Age, grip strength, and snow removal were independently associated with MVPA ( $p = 0.023$ ,  $p = 0.021$ , and  $p = 0.005$ , respectively). The adjusted  $R^2$  value was 0.58. The adjusted  $R^2$  for MVPA was better than that for total physical activity.

#### Discussion

It is important to consider regional characteristics to improve the level of physical activity of hemodialysis patients. In snowbelt regions, snow removal during the winter is a common and essential physical activity. However, there has been no previous study on the effect of snow removal on hemodialysis patients' level of physical activity.

The median level of physical activity of hemodialysis patients was 993 MET-minutes/week. Among 320 Chinese dialysis patients with an average age of 58 years, the median physical activity level was 1533 MET-min/week [18]. The patients in the present study were relatively inactive compared to those in previous studies. The average age of patients in this study was 69.6 years, which is older than patients in previous studies. The univariate linear regression analysis showed that age was associated with physical activity. The older age of participants in this study compared with participants in previous studies may be associated with the lower activity level of our participants. In addition, physical activity levels tend to decrease in the winter, which was when this study took place [19–21]. Thus, regionality, age, and season must be taken into account when examining physical activity.

The snow remover group had a high physical activity level with good physical function in terms of grip strength, STS score, and gait speed. To our knowledge, there are no reports that snow removal has improved physical functioning. However, previous studies have reported that there is a positive correlation between physical functioning and physical activity in healthy subjects [4, 5], which is also supported by the present study. In healthy subjects, snow removal is associated with high physical activity levels [22]. In this study, snow removal was associated with MVPA in hemodialysis patients. Exercise therapy is recommended for hemodialysis patients to improve exercise tolerance, walking ability, and quality of life [10]. The guidelines for renal rehabilitation

**Table 2** Demographic characteristics

	All patient (n = 28)	Snow remover (n = 10)	Non-snow remover (n = 18)	p value
Age (years)	69.6±15.4	64.6±13.9	72.4±15.9	0.191
Men	19 (67.9)	8 (80.0)	10 (55.6)	0.190
BMI (kg/m <sup>2</sup> )	23.0±4.5	23.7±3.5	22.6±5.1	0.504
Original disease (n)				
Diabetic nephropathy	10 (35.7)	5 (50.0)	5 (27.8)	
Hypertensive nephrosclerosis	7 (25.0)	3 (30.0)	4 (22.2)	
Chronic glomerulonephritis	4 (14.3)	0 (0.0)	4 (22.2)	
Other	5 (17.9)	1 (10.0)	4 (22.2)	
Unknown	2 (7.1)	1 (10.0)	1 (5.6)	
Time on dialysis (years)	7.4±8.6	8.2±11.6	6.8±6.8	0.740
Comorbidities (n)				
Hypertension	24 (85.7)	8 (80.0)	16 (88.9)	
Diabetes mellitus	13 (46.4)	6 (60.0)	7 (38.9)	
Chronic heart failure	8 (28.6)	4 (40.0)	4 (22.2)	
Dyslipidemia	6 (21.4)	3 (30.0)	3 (16.7)	
Ischemic heart disease	4 (14.3)	3 (30.0)	1 (5.6)	
Cerebrovascular disease	2 (7.1)	0 (0.0)	2 (11.1)	
Household				
Alone (n)	2 (7.1)	2 (20.0)	0 (0.0)	0.119
Blood laboratory data				
Hemoglobin (mg/dl)	11.1±0.8	11.3±0.7	11.0±0.8	0.293
Serum albumin (mg/dl)	3.5±0.4	3.5±0.4	3.6±0.4	0.630
C-reactive protein (mg/dl)	0.5±0.7	0.8±1.0	0.3±0.5	0.102

Values are means ± standard deviation or number of subjects per group (n) with percentages  
 BMI body mass index

**Table 3** Clinical characteristics

	All patients (n = 28)	Snow remover (n = 10)	Non-snow remover (n = 18)	p value
Physical function				
Grip strength (kg)	20.7±9.1	23.8±7.8	19.6±9.6	0.028
STS (s)	13.8±8.4	9.7±1.0	16.0±9.8	0.015
Gait speed (m/s)	1.0±0.3	1.2±0.2	1.0±0.3	0.038
SMI (kg/m <sup>2</sup> )	6.1±0.7	6.1±0.4	6.2±0.8	0.719
Frailty (n)	12 (42.9)	1 (10.0)	11 (61.1)	0.011
Mental function				
PHQ-9 (point)	7.3±4.4	8.5±5.9	6.7±3.4	0.383
Physical activity				
Total activity (MET-min/week)	993 (1243)	1939 (800)	693 (463)	0.005
MVPA (MET-min/week)	300 (580)	640 (680)	90 (180)	0.003

Values are means ± standard deviation or number of subjects per group (n) with percentages. Total activity is median (interquartile range)  
 STS sit-to-stand test, SMI Skeletal Muscle Index, PHQ-9 Patient Health Questionnaire-9, MVPA moderate-to-vigorous physical activity

**Table 4** Predictors of total physical activity

Variable	Total physical activity					
	Univariate analysis			Multivariate analysis		
	B (SE)	95% CI for B	p value	B (SE)	95% CI for B	p value
Age	-30.2 (9.3)	-49.4 to -11.0	0.003	-14.6 (8.8)	-32.7 to 3.6	0.11
Gender	345.9 (342.2)	-357.4 to 1049.2	0.321			
BMI	87.4 (33.5)	-18.6 to 156.2	0.065			
Dialysis duration	-11.0 (19.6)	-51.3 to 29.3	0.579			
Hemoglobin	214.8 (215.6)	-228.5 to 658.1	0.328			
Serum albumin	940.0 (444.9)	-25.5 to 1854.5	0.064			
C-reactive protein	53.0 (235.7)	-431.5 to 537.4	0.824			
Grip strength	43.0 (16.7)	8.7 to 77.3	0.016	32.1 (14.4)	2.4 to 61.7	0.035
STS	-44.1 (18.4)	-81.8 to -6.3	0.024			
Gait speed	1282.9 (486.3)	283.4 to 2282.5	0.044			
SMI	124.3 (71.2)	-22.3 to 270.6	0.930			
PHQ-9	10.0 (38.3)	-68.7 to 88.7	0.797			
Snow removal	1052.3 (281.2)	474.2 to 1630.3	0.001	919.2 (268.8)	365.7 to 1472.8	0.002

model  $R^2 = 0.46$ , adjusted  $R^2 = 0.41$ , intercept = 253.5

SE standard error, CI confidence interval, STS sit-to-stand test, SMI Skeletal Muscle Index, PHQ-9 Patient Health Questionnaire-9

recommend both aerobic exercise and resistance training [10]. Furthermore, a high physical activity level leads to decreased mortality in hemodialysis patients [1, 2]. Thus, it is suggested that maintaining physical activity by removing snow could be important for patient management in snowbelts.

One of the patients who performed snow removal was frail. This patient lived alone and had to remove snow by himself. The oxygen uptake ( $VO_2$ ) of healthy males

who removed snow using a shovel was 63% of the maximum  $VO_2$  [23], which corresponds to moderate-intensity exercise. In addition, the exercise load of those who used snow pushers was even higher. In the present study, we did not ask about the method of snow removal. However, snow removal and MVPA were independently related. If a patient's physical strength decreases, the exercise load may increase. It has been reported that physical inactivity is related to cardiac events

**Table 5** Predictors of MVPA

Variable	MVPA					
	Univariate analysis			Multivariate analysis		
	B (SE)	95% CI for B	p value	B (SE)	95% CI for B	p value
Age	-19.3 (5.2)	-29.1 to -8.6	0.001	-11.2 (4.6)	-20.6 to -1.7	0.023
Gender	263.4 (195.7)	-138.8 to 665.7	0.190			
BMI	34.6 (20.7)	-8.0 to 77.2	0.107			
Dialysis duration	-3.7 (11.4)	-27.2 to 19.7	0.746			
Hemoglobin	150.0 (124.0)	-104.9 to 405.0	0.237			
Serum albumin	721.3 (241.0)	-26.0 to 1216.7	0.096			
C-reactive protein	4.6 (136.9)	-236.8 to 285.9	0.974			
Grip strength	32.2 (8.8)	14.0 to 50.3	0.001	19.1 (7.7)	3.2 to 35.0	0.021
STS	-25.8 (10.6)	-47.6 to -3.9	0.023			
Gait speed	864.3 (268.7)	312.0 to 1416.6	0.003			
SMI	73.1 (41.3)	-11.7 to 157.9	0.088			
PHQ-9	1.8 (22.2)	-43.9 to 47.5	0.936			
Snow removal	581.2 (167.2)	237.5 to 925.0	0.002	415.2 (133.8)	139.0 to 691.4	0.005

Model  $R^2 = 0.63$ , adjusted  $R^2 = 0.58$ , intercept = 715.3

MVPA moderate-to-vigorous physical activity, SE standard error, CI confidence interval, STS sit-to-stand test, SMI Skeletal Muscle Index, PHQ-9 Patient Health Questionnaire-9

during snow removal [24]. In addition, many accidents involving falling while removing snow from a rooftop are reported every year [8]. Snow removal may be a hazardous activity when performed by people with poor physical function. Snow removal is a necessary activity during the winter, but whether it is feasible for an individual patient to engage in it should be determined based on the consideration of that patient's physical strength and social background. There are various types of administrative support available with regard to snow removal for elderly individuals living alone, although none of the patients in this study accessed such forms of administrative support. For example, there is a subsidy for outsourcing snow removal to a company. Medical staff members should consider proposing such services as appropriate.

This study has several limitations. First, we did not ask about the duration and frequency of snow removal. A detailed evaluation of how snow removal is performed is needed. Furthermore, because this study enrolled hemodialysis patients in a snowbelt area, the results are not directly applicable to patients in other areas. The amount of snowfall in 2020 was lower than usual, which may have affected the results. Another limitation is that physical activity was evaluated using a questionnaire. In recent years, many studies have evaluated physical activity using accelerometers. Thus, it is necessary to perform a more objective evaluation in future studies. This study was a cross-sectional study based on evaluations performed during the winter and did not examine the effects of activity during the summer. The relationship between snow removal and physical activity in the summer has not been studied. And, the sample size was small, and in the multivariate linear regression analysis, the adjusted  $R^2$  value was 0.41. Therefore, it is necessary to examine factors that directly influence physical activity. Lastly, this study is a cross-sectional study and does not provide any information regarding "cause and effect relationship" between snow removal habit and higher physical function. This study might only reflect the present condition that "subjects with poorer physical ability are not able to perform snow removal." Therefore, a prospective cohort study needs to clarify the relationship between snow removal habit and physical function.

## Conclusion

Hemodialysis patients living in a snowbelt who performed snow removal maintained high physical activity levels and adequate physical functioning, such as grip strength. However, some frail patients have to remove snow by themselves because they live alone. Because snow removal is a high-intensity activity, it is necessary to evaluate patients' physical functioning and social context and to pay attention to the possibility of overexertion.

## Abbreviations

BMI: Body mass index; STS: Sit-to-stand test; SMI: Skeletal muscle index; PHQ-9: Patient Health Questionnaire-9; IPAQ: International Physical Activity Questionnaire;  $VO_2$ : Oxygen uptake; MVPA: Moderate-to-vigorous intensity physical activity

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## Authors' contributions

YS was involved in the study design and in the writing of the manuscript. YS participated in the study procedure implementation and data collection. NI reviewed and revised the manuscript. All authors read and approved the final manuscript.

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## Availability of data and materials

The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

## Declarations

### Ethics approval and consent to participate

The institutional review board of the ethics committee at Uonuma Kikan Hospital approved the study protocol (no. 30-056), and the study was conducted according to the principles of the Declaration of Helsinki.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

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