学 位 論 文

Effect of seasonal variation on physical activity and frailty among community dwelling elderly living in snowy cold regions

（積雪寒冷地に居住する高齢者における身体活動量とフレイルに対する季節変動の影響）

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Abstract

Background: Although the benefits of physical activity are well-known, levels of physical inactivity are increasing in many countries. Physical activity, particularly for preventive care of the elderly, must be encouraged. The level of physical activity undertaken by people is influenced by season; however, little is known about seasonal fluctuations of physical activity and its relation to muscle strength. Generally, physical activity declines in winter in snowy-cold regions. Physical activity is a diagnostic criterion for frailty, hence it is possible to assume that the status of frailty fluctuates depending on the season.

Objectives: The current study had three aims: 1) to clarify the association between physical activity levels and muscle strength/skeletal muscle mass during non-snowy and snowy seasons in northern Japan, 2) to investigate the effect of lower limb muscle strength training programme for elderly individuals on the physical activity during the snowy season, assuming physical strength benefits promoting physical activity, 3) to clarify the phenomenon of seasonal frailty and its association with health-related quality of life.

Methods: Participants were community-dwelling elderly people aged 65 years or older

living in Tobetsu, northern Japan. People who had a certificate needed long-term care insurance which is run by municipal governments to provide long-term care services were excluded.

In Chapter Ⅰ, a 30-s chair-stand test (CS-30) and body composition measurements using bioelectrical impedance analysis were conducted prior to physical activity measurement using a three-dimensional acceleration sensor in both non-snowy and snowy seasons. Daily steps for the non-snowy and snowy seasons were compared using Welch's t test. The association between the CS-30/skeletal muscle index and daily steps in both seasons was estimated by fitting multiple linear regression models, with age and sex as covariates.

In Chapter Ⅱ, daily step counts were measured during the snowy season in 2018 (with no exercise intervention) and 2019 (after the exercise intervention). Physical function was measured before and after the intervention, including body mass index, CS-30, grip strength, normal gait speed, short-test battery for locomotive syndrome, Kihon checklist (KCL), and 25-question geriatric locomotive function scale. The 12-week supervised exercise programme included a 1-hour exercise routine, performed twice per week was conducted. The exercise programme consisted of 10-15 min warm-up, low-intensity resistance training for the lower limbs and trunk (20-30 min), ergometer cycling as moderate aerobic exercise (10-15 min), and a cool-down.

In Chapter Ⅲ, a questionnaire was administered twice: in the snowy season and non-snowy season. Frailty was judged using KCL. Self-rated health, life satisfaction, exercise satisfaction, and quality of life (QOL) scores for both seasons were obtained. Depending on the status of frailty in both seasons, four classifications were established (robustness, non-snowy frailty, snowy frailty, and year-long frailty). Frailty was judged by 4 ≤ of KCL score.

Results: Average daily step counts were significantly lower during the snowy season, compared to the non-snowy season ($P < .01$). The CS-30 in the snowy season alone was significantly associated with daily step counts. Multiple linear regression analyses results revealed that, for the same muscle strength in both seasons, the daily step counts during the snowy season were fewer than those during the non-snowy season (Chapter Ⅰ).

To examine the effect of muscle strength training programme on the physical activity during the snowy season, 11 women and 3 men (78.6±5.2 years old) were participated the programme. The exercise intervention improved physical function, with a significant increase in step count among individuals with lower baseline strength. Improved lower limb strength positively correlated with an increase in step count (Chapter Ⅱ).

Regarding the investigation of seasonal frailty by questionnaire research, 144 valid responses were obtained. In today, 45% participants exhibited frailty throughout the year, 31% were robust throughout the year, and 10% exhibited frailty during either the snowy or non-snowy season. A multiple regression equation to predict the status of year-long frailty revealed cognitive decline, mood of depression, self-rated health, low physical strength and social frailty in the non-snowy season as the predictive factors. In addition, KCL score in the non-snowy season was the strongest predictor of QOL score (Chapter Ⅲ).

Conclusion: The muscle strength required to perform adequate physical activity depended on season. Lower limb muscle strengthening is an effective intervention to improve physical activity during the snowy season among community-dwelling elderly. The status of frailty fluctuates seasonally in an individual, whose status vacillates between the conditions of advanced frailty and robustness. Frailty in the non-snowy season is considered a step in the progression of physical dysfunction.

General Introduction

In today's super-aged society, health promotion of elderly people is an urgent issue. It is important for everyone to live a healthy and independent life until their senior years, which is crucial not only for human dignity but also for effective utilization of limited funds and human resources in medicine or long-term care. Although physical and mental deterioration due to aging is a natural process for everyone, it is well known that appropriate exercise is effective for health promotion. The benefit derived from physical activity has been reported (Pete et al. 1995; NIH Consensus Development Panel. 1996). Maintaining regular physical activity is one of the measures to be taken for preventive care of older people.

In terms of promoting physical activity, previous studies mostly focused on behavior modification (Hobbs et al. 2013; Conn et al. 2011). Little has been reported about the relationship between physical capacity or function and physical activity. Cooper and colleagues (2017) reported that a higher level of moderate-to-vigorous physical activity does not affect future muscle strength, whereas muscle strength is a determinant of future activity level. In general, physical activity decreases as age increases; however, among the elderly with sufficient muscle strength, the level of physical activity was maintained/barely decreased.

Particularly in the cold snowy regions, regular physical activity is often limited during winter due to the cold temperature and snow (Arnardottir et al. 2017; Togo et al. 2005). Although the decline in physical activity during the cold snowy season is for a limited period only, it has been reported that negative effect on physical function occurs even over the short term (Krogh-Madsen et al. 2101; Olsen et al. 2008). However, if muscle strength is a key underlying component of physical activity (Cooper et al. 2017), older individuals with sufficient lower limb muscle strength might be able to maintain their physical activity levels regardless of the season.

Physical activity is one of the factors of diagnosis criterion of frailty (Fried et al. 2001). No unified definition of frailty is yet to be decided but it is considered that a status of low resilience to stress caused by the decreasing reserve capacity followed by aging. Due to seasonal fluctuation in physical activity, the status of frailty might change depending on the season. Assuming seasonal change in physical activity depends on muscle strength, seasonal status of frailty depends on muscle strength likewise and might be an indicator of the seriousness of the frailty; namely with a progress of frailty, elderly firstly tend to decrease their amount of physical activity in snowy season, then they will be frail regardless of the season with further progress.

Outline of the study

In this thesis, the author described seasonal fluctuation in physical activity and frailty, particularly, regarding the association of lower limb muscle strength.

In Chapter Ⅰ, the difference in the association between physical activity and lower limb muscle in both snowy season and non-snowy season is discussed. In Chapter Ⅱ, the author compares physical activity (daily steps) in 2 straight snowy seasons; The first winter season and next one after 3 months supervised exercise intervention in order to clarify the effect of the exercise intervention on the physical activity in the snowy season. In Chapter Ⅲ, the author confirms the phenomenon of “seasonal frailty”, and investigates the association between the status of frailty and health-related quality of life.

I. Impact of season on the association between muscle strength/volume and physical activity among community-dwelling elderly people living in snowy-cold regions*

Aim of the study

To clarify the association between physical activity level and muscle strength/skeletal muscle mass during non-snowy and snowy seasons.

Methods

Participants were community-dwelling elderly people aged 65 years or older who regularly attended senior club events in Tobetsu-town, northern Japan. Tobetsu-town is designated as a special heavy snowfall zone. The yearly average cumulative amount of snowfall is more than 8 m (Meteorological Agency. 2018). Prior to enrollment in this study, written informed consent was obtained from all participants.

Measurement of lower limb muscle strength and volume

To estimate lower limb muscle strength, the 30-second chair-stand test (CS-30) was

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conducted as demonstrated in a previous study (Nakatani et al. 2002). Skeletal muscle volume was measured with bioelectrical impedance analysis using InBody s10 (InBody Japan, Tokyo, Japan). Per the criterion provided by the Asian Working Group for Sarcopenia (Chen et al. 2014), the skeletal muscle mass index (SMI) was calculated. From March to July 2017, 59 participants underwent these measurements.

Physical activity during the non-snowy season

To count participants' daily steps from July to October 2017, the wearable fitness tracker Misfit Shine2 (Misfit, San Francisco, United States) with confirmed validity and reliability (Straiton N et al. 2018) was used. Participants wore the tracker for more than seven complete days. A dedicated application for the tracker was used to visualize daily step counts, and average daily steps were used for statistical analyses. In this measurement, 54 out of 59 people participated; however, the data of 4 people were lost due to bugs while synchronizing the data with the application.

Physical activity during the snowy season

Participants attached not only the same wearable fitness tracker, but also a Kenz Lifecorder GS (Suzuken, Nagoya, Japan) for insurance against data deficits during the snowy season. The author explained the circumstances to participants and added the Lifecorder to monitor step counts. Participants were instructed to detach the Lifecorder only while bathing and sleeping. Although the data from the fitness tracker were used preferentially, there were nine instances of data deficit. To compensate, the compatibility of step counts measured by the wearable fitness tracker and Lifecorder was checked using Bland and Altman's method (Bland and Altman. 1986). Accordingly, 78 pairs of step count data were analyzed; the average and standard deviation of the differences in paired data (bias) were 265.8 and 1455.4, respectively. Although 95% of the data were within limits of agreement, a proportionality effect in which the fitness tracker was underestimated by over 3300 steps was observed. To convert data from the Lifecorder to those in the fitness tracker, a single regression analysis was conducted to obtain a regression equation and the step counts estimated by the regression equation were applied for the nine data deficits. Daily step counts for 29 people were obtained. Of those, 24 participated in both non-snowy and snowy season measurements. In other words, 26 people out of 50, who had their step counts measured in the non-snowy season, did not have their step counts measured in the snowy season.

Statistical analyses

Age, body mass index (BMI), SMI, CS-30, and daily steps in the non-snowy and snowy seasons were compared using Welch's t-test. For both seasons, the associations between CS-30/SMI and daily steps were estimated by fitting multiple linear regression models, in which age and sex were set as covariates. All data were analyzed using JMP Pro 13.1.0 (SAS Inc., United States), with the significance level set as 5%.

Results

Table 1 displays the characteristics of participants in both non-snowy and snowy seasons. No significant difference was observed between the two groups regarding mean age, BMI, SMI, and CS-30. The average daily step counts for Japanese people aged 70 years or older were 5744 steps and 4856 steps for men and women, respectively, according to a national survey held in 2016 (Ministry of Health, Labour and Welfare. 2018). Among men, daily step counts for both seasons were lower than the average. On the other hand, daily step counts for women during the non-snowy season constituted approximately 150% of the Japanese national average; however, the step counts drastically declined until they fell lower than the Japanese average during the snowy season. The average daily step counts were significantly lower during the snowy season, compared to the non-snowy season ($P < .01$). Table 2 displays the association between CS-30/SMI and daily step counts for both seasons.

Table 1. Physical characteristics of participants in both non-snowy/snowy seasons

	Non-snowy season			Snowy season			P
	Total	Male	Female	Total	Male	Female	
Number of participants	50	13	37	29	8	21	-
Age	77.8 ± 5.3	79.5 ± 5.3	77.2 ± 5.3	78.4 ± 5.8	80.6 ± 5.5	77.5 ± 5.8	.65
BMI	24.5 ± 3.1	25.0 ± 2.8	24.3 ± 3.2	25.6 ± 3.5	26.8 ± 2.3	25.1 ± 3.8	.16
SMI	6.4 ± 1.0	7.4 ± 0.8	6.1 ± 0.8	6.6 ± 0.9	7.6 ± 0.6	6.2 ± 0.7	.43
CS-30	15.4 ± 4.3	13.3 ± 3.7	16.1 ± 4.3	15.6 ± 5.4	12.6 ± 4.5	16.8 ± 5.4	.86
Daily step counts	6.5 ± 3.2	4.6 ± 2.2	7.2 ± 3.2	4.2 ± 2.0	3.7 ± 2.3	4.4 ± 1.9	< .01

Note: Daily step counts are displayed in units of one thousand. P-values are between both seasons among all participants. BMI: body mass index, SMI: skeletal muscle mass index, CS-30: a 30-second chair-stand test

Table 2. Effect of CS-30/SMI on daily step counts according to multiple linear regression analysis

	Daily steps (non-snowy season)				Daily steps (snowy sesason)			
	β	P	β	P	β	P	β	P
CS-30	0.20	0.17			0.72	0.00		
SMI			0.22	0.13			0.60	0.03
Age	-0.11	0.42	-0.22	0.21	-0.06	0.95	-0.36	0.07
Sex	0.28	0.05	0.45	0.01	-0.07	0.63	0.50	0.05
Adjusted R^2	0.14		0.13		0.44		0.16	
Prob<F	0.02		0.02		0.00		0.07	

Note: Covariates included age, sex, and CS-30 or SMI. Two separate models were run for each season. Data are presented as standardized β (β) and P-values (P). A negative β-value indicates an inverse relationship. CS-30: a 30-second chair-stand test, SMI: skeletal muscle mass index

On setting daily steps during the non-snowy season as a dependent variable, neither CS-30 nor SMI were significant predictors of daily step counts, although both the regression equations were significant. When the dependent variable was set as daily steps during the snowy season, the regression equation for SMI was non-significant ($P = .07$), although the standardized partial regression coefficients were relatively high ($\beta = 0.60$) and $P = .03$. For CS-30, the regression equation was significant, and CS-30 was the main component of the equation, as well. To simplify the association between muscle strength and daily step counts, Tables 3 and 4 display the correlation between CS-30/SMI and daily step counts, and the regression equation stratified by sex, since the author judged that age had no influence according to the results demonstrated in Table 2.

Table 3. Effect of CS-30 on daily step counts according to single regression analysis stratified by sex

	Non-snowy		Snowy	
	Male	Female	Male	Female
Number of participants	13	37	8	21
R	0.08	0.27	0.87	0.64
P	.80	.10	.01	< .001
Intercepts	3966	3872	-940	629
Gradients	47	205	363	224

Table 4. Effect of SMI on daily step counts according to single regression analysis stratified by sex

	Non-snowy		Snowy	
	Male	Female	Male	Female
Number of participants	13	37	8	21
R	0.19	0.12	0.15	0.38
P	0.54	0.4	0.72	0.08
Intercepts	543	4253	232	-1965
Gradients	549	482	447	1021

As indicated by the multiple linear regression model, no correlation was observed during the non-snowy season, whereas a significant positive correlation was observed during the snowy season between physical activity and muscle strength. The single regression analysis indicated the same tendency as the multiple linear regression model. When daily step counts were the dependent variable, the intercepts were approximately 4000 for both male and female participants in the non-snowy season, whereas in the snowy season, they were approximately 600 for female participants, and 1000 for male participants. If the possible values of CS-30 range 0–40, according to the judgment criteria, even when the regression equation of the non-snowy season was not considered significant, daily step counts in the snowy season were overwhelmingly lower than those during the non-snowy season for the same level of muscle strength.

Discussion

Our results reveal that daily step counts during the snowy season were significantly lower than during the non-snowy season. This supports the findings of most previous studies (Matthews. 2001; Tudor-Locke et al. 2004; Hamilton et al. 2008; Newman et al. 2009). In this study, the association between lower limb muscle strength/volume and daily steps was examined prospectively. As a result, CS-30 and average daily step counts demonstrate a significant positive correlation only during the snowy season. Interestingly, this correlation was not observed during the non-snowy season. Although the SMI demonstrated a similar tendency as muscle strength, no significant difference was confirmed.

In the snowy season, the condition of roads completely differs from that in the non-snowy season; during the snowy season, roads are frozen or have a snowy surface. A person's strategy of walking on such roads also differs from his or her normal gait. Regarding walking on frozen road surfaces, detailed kinematics were analyzed. The flexion/extension moment of rotation of the hip joint increases while walking on a slippery floor (Nagaoka et al. 2009). To avoid slipping on a frozen road surface, increased flexion/extension movement enables the floor reaction force to be adjusted vertically. This means that greater muscle strength of hip flexion/extension is required to avoid slipping on a frozen road. In addition, in a snowy season environment, people must push the snow aside using their legs. Moreover, rubber boots—which are often worn during the snowy season—and winter clothes tend to be heavier than normal clothing. By comprehensively considering these factors, the author speculates that greater muscle strength is required for people to walk outside in snowy season.

Physical activity is essential for the promotion of health. Studies have reported various effects of physical activity, such as the reduction of mortality rate and risk of cardiovascular disease, metabolic diseases, obesity, falls, dementia, osteoporosis, and musculoskeletal diseases. The quantity–response association between physical activity and health was reported; however, even very-low-intensity physical activity is effective in promoting health. Engagement in physical activity is affected by factors such as pedestrian infrastructure and road safety (Moran et al. 2014). In addition, studies have examined various types of interventions to promote physical activity (Hobbs et al. 2013; Conn et al. 2011); however, the association between physical capacity and activities of daily living has not been well investigated. This research gap was successfully addressed by the current study. As mentioned earlier, Cooper and colleagues (Cooper et al. 2017) reported that older adults who maintained/improved their muscle strength were more likely to increase their levels of physical activity during follow-up, and those who increased their level of physical activity did not increase their muscle strength. The results of the current study reveal that muscle strength is a key factor that affects the level of physical activity of individuals, which coincides with the results reported by Cooper and colleagues. Low muscle strength is likely one of the causes of inactivity. Conversely, if muscle strength is improved with appropriate interventions, it may promote physical activity.

The author showed that muscle weakness is a plausible cause of inactivity during winter; however, inactivity can occur for various reasons. The weather, such as temperature, rain, or wind, influences physical activity (Chan et al. 2006). Further, regardless of season, people with a fear of falling tend to curtail activities (Howland et al. 1998). To promote physical activity, the usage of a cane, non-slip shoes, or such items should be considered to offset individuals' fear of falling. In addition, to understand how people seek necessary information to avoid falling while walking outdoors, especially on slippery road surfaces, it is vital to dispel people's fear of falling. Suzuki and colleagues reported that elderly people tend to pay much more attention to other things rather than the walking path or their footing on an icy road (Suzuki et al. 2012). Auditory information or sensations received from the sole of the foot are potential information to avoid falling as well as visual information. Such understanding of walking characteristics may enlighten elderly adults and prevent falling.

Since there was a seasonal difference in the association between lower limb muscle strength and daily step counts, the author assumes that the muscle strength required to perform sufficient physical activity depends on the season. In other words, adequate muscle strength guarantees sufficient physical activity regardless of the season; however, when muscle strength declines to a certain level, sufficient physical activity can be guaranteed in the non-snowy season alone. Schematically, Fig. 1 presents this hypothesis.

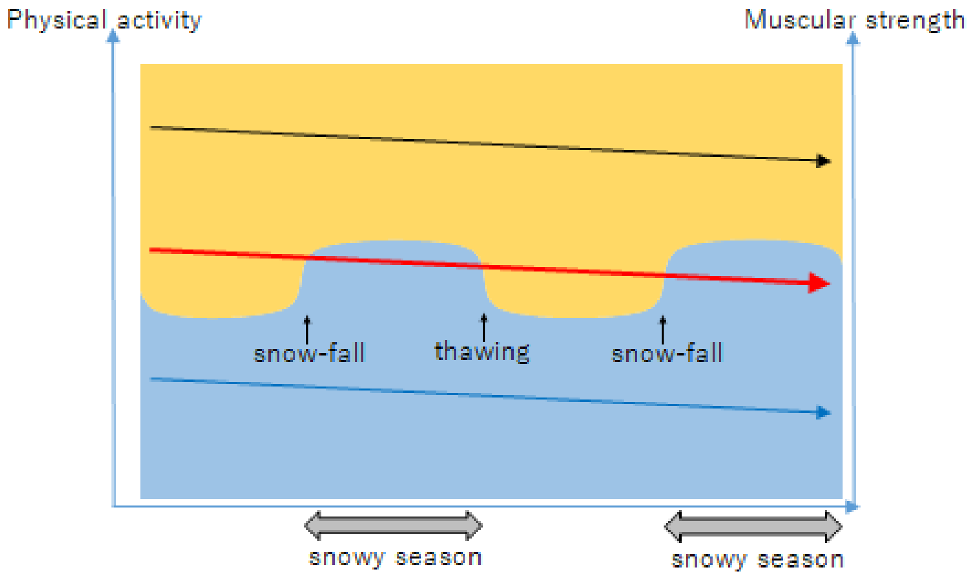

Fig 1. Hypothesis of seasonal fluctuation on muscle strength required to perform physical activity. The vertical axes represent muscle strength and physical activity. The background color refers to physical activity; the blue zone implies physically inactive, whereas the orange zone implies active. Three different levels of muscle strength are displayed using the three arrows in Fig. 1. The arrows represent individuals with different muscle strength levels; the black, blue, and red arrows represent adequate muscle strength, remarkably low muscle strength, and intermediate muscle strengths, respectively. The gentle downward slope of each arrow represents muscle weakness due to aging. Although these arrows may slope downward due to a certain event or the degree of slope may differ between individuals, the arrows are presented as even lines here. The black arrow indicates individuals who are physically active throughout the year, and, likewise, blue indicates those who are inactive. The individuals represented by the red arrow show seasonal fluctuations in physical activity, with adequate physical activity during the non-snowy season and inactivity during the snowy season

The level of lower limb muscle strength required to be physically active is higher in the snowy, rather than the non-snowy season, as mentioned above. On the premise of lower limb muscle strength weakening due to aging, when healthy elderly people reach a certain level of muscle strength, they can be physically active during the non-snowy season but be inactive during the snowy season. Although a healthy elderly person's strength gradually weakens with the passage of time, activity in the non-snowy season, coupled with inactivity in the snowy season, illustrates the early stages of elderly frailty. In other words, seasonal fluctuations in physical activity among community-dwelling elderly people in snowy-cold regions could be a key factor in the early diagnosis of frailty. Moreover, this presents further implications for clarifying the methods/timing of intervention or resilience during the snowy and non-snowy seasons, although the hypothesis requires further study.

This study had some limitations. First, the sample size was small; however, the study applies appropriate statistical analyses. Second, the use of two different instruments to measure physical activity levels required the use of suitable conversion methods. Third, physical activity was evaluated using daily steps alone, which does not reflect activity intensity. Fourth, alertness for falling might affect physical activity levels; however, this point was not considered in the current study.

Conclusion

In this study, the author focused on the association between seasonal changes in physical activity and lower limb muscle strength/volume among the elderly. Similar to previous studies, the author confirmed that the level of physical activity decreased during the snowy season. The author hypothesized that there is a seasonal difference in the lower limb muscle strength that is required to maintain the level of physical activity. Further, the author obtained basic knowledge to promote the health of elderly people living in snowy-cold regions.

II. Effect of a lower limb strength training programme on physical activity during the snowy season among community-dwelling elderly individuals

Aim of the study

The aim of the current research was to evaluate the effect of a lower limb strength training programme for elderly individuals, performed before the winter season, on daily step counts during the winter season, compared to step counts obtained the previous year without an exercise intervention.

Methods

Participants were community-dwelling elderly people, aged ≥65 years, who regularly attended a community-based activity programme in Ishikari-Tobetsu, northern Japan. All participants provided written informed consent. Invitation of the recruitment was announced at community hall while candidate participants were attending community-based activity. Inclusion criteria were aged ≥65 years, living independently in community, and not diagnosed dementia. Finally, 35 individuals were recruited.

Measurement of daily step counts during the snowy season in 2018

Daily step counts for 35 individuals were measured from January to March 2018, using both the wearable Misfit SHINE2 (Misfit, San Francisco, USA) and Kenz Lifecorder GS (Suzuken, Nagoya, Japan) step tracker. The SHINE2 tracker was dominantly used as it can be worn day and night, while the Kenz Lifecorder, which requires doffing during bathing, used a backup system in case of data deficits. Participants wore the SHINE2 tracker and Kenz Lifecorder for more than seven complete days. For the Misfit SHINE2 tracker and the Kenz Lifecorder system, the average daily step count was obtained using the dedicated application. All data were obtained from the Misfit SHINE2 tracker; hence, no data loss was observed.

Enrolment of exercise intervention

Thirty-five individuals whose daily step counts in the snowy season of 2018 were measured were approached for enrolment into our study for baseline measurement and for completion of the 12-week exercise intervention programme, conducted from September to November 2018. Of these individuals, 2 could not be contacted at the time of baseline measurement and 14 declined participation, leaving 19 prospective participants. Of these 19 participants, one sustained a fracture, leaving 18 participants for initial evaluation. Fourteen completed the exercise intervention since 4 dropped out (2 for health problem, 2 for their own convenience) (Fig 1).

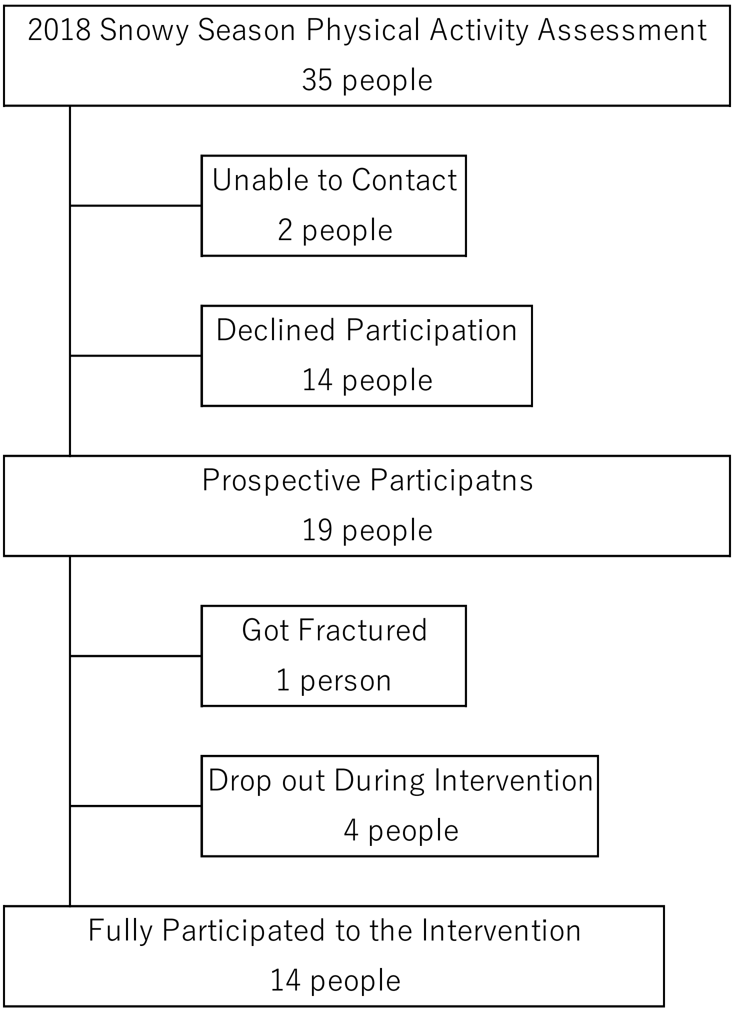

Figure 1. Participant enrollment flow chart

Assessment of physical function and frailty before exercise intervention

Initial assessment of physical function was performed early in September 2018, including the following measurements: body mass index (BMI, kg/m2), 30-s chair stand test (CS-30; Jones et al. 1999; Nakatani et al. 2002), grip strength (measured using a dynamometer), normal gait speed, short-test battery for locomotive syndrome (including the stand-up and two-step tests; Nakamura and Ogata, 2016), Kihon checklist (Arai et al. 2015; Ogawa et al. 2011), and the 25-question geriatric locomotive function scale (GLFS-25; Seichi et al. 2012). CS-30 was adopted as the main index to confirm the effectiveness of the exercise intervention (lower muscle limb strength). The Kihon checklist, which was developed by the Japanese Ministry of Health, Labor and Welfare, was chosen to assess the status of frailty (Satake et al. 2016; Sewo et al. 2016; Satake et al. 2017). The Kihon checklist consisted of 25 yes/no questions, and the total score ranges from 0 to 25. A cut-off point of ≥8 is considered to indicate frailty. It is also categorised into seven domains, such as activities of daily living, physical strength, nutrition, oral function, isolation, cognition, and mood of depression which allow us to understand the main factor of frailty. GLFS-25 has 25 questions, and each has a 5-point grading scale (0-4 points) leading to a total of 100 points of simple scoring.

Exercise intervention programme

The 12-week exercise programme was conducted from September through November 2018. The programme included a 1-h exercise routine, performed twice per week. Subjects were encouraged to perform the programme at home when unable to attend the schedule sections, and on the next session, the contents of home exercise were confirmed orally. Of the 14 subjects enrolled into the study, only 2 completed the full 24 sessions of the exercise training programme. On average, subjects completed 21.6 of the 24 sessions.

The exercise programme included the following components: a 10-15 min warm-up; resistance training for the lower limbs and trunk (20-30 min), ergometer cycling (10-15 min), and a cool-down period as shown in a previous study (Yoshimura et al. 2017). Prior to the exercise programme, subjects participated in an education session regarding the principles of muscle strengthening. Based on current exercise guidelines, low-intensity resistance exercises were used, performed at a low velocity (Tanimoto and Ishii. 2005). The resistance exercise programme consisted of the following exercises: knee extension and hip flexion on chair sitting position, ankle extension/flexion, knee flexion, step and weight shifting and squat on standing position, bridge with both shoulders grounded, straight leg raising in spine and side lying, scissors kicking, and plank on elbows or side plank on lying position. The initial duration of the muscle contraction was determined based on self-report levels of muscle fatigue, with subjects encouraged to perform as many repetitions as possible during class-style sessions. The intensity cycling was adjusted to 60%-70% of the expected maximum heart rate which was calculated by Karvonen formula, as moderate intensity. Resting heart rate was measured every week, and the target heart rate during exercise was adjusted accordingly. The duration of the muscle contraction and the number of repetition of the resistance exercise were increased, as possible, through the intervention period.

Post-intervention assessment

Measures of physical function were repeated after the last exercise session, for comparison to pre-intervention physical function. A subjective assessment of the intervention was included.

Measurement of daily step counts during the snowy season in 2019

Daily step count measurements were iterated in January 2019 using the same method as that used in the previous year. All data were obtained from the Misfit SHINE2 tracker.

Statistical analysis

The average daily step count during the snowy season between 2018 and 2019, the main outcome of this study, was compared using a paired t-test. To confirm the effect of the exercise intervention, pre- and post-interventions measures of physical function (BMI, CS-30, grip strength, normal gait speed, and Kihon checklist) were compared using a paired t-test after ensuring the normality of the data distribution. Change in the GLFS-25 and 2-step test, before and after the intervention, was evaluated using the Wilcoxon rank test. The author further evaluated the CS-30 and daily step count stratified by the level of grip strength before the exercise intervention, the level of daily step counts measured in 2018 (year before the intervention programme), and the presence of body pain after the exercise intervention. Stratification for analysis was performed as follows: the criteria of the Asian working group on sarcopenia was used for grip strength (Chen et al. 2014), and step count was divided into high and low using the cut-off of 4746 steps as previously reported for elderly individuals in Japan (Ministry of Health, Labour and Welfare, Japan. 2016). The presence of body pain was evaluated using the 4 pain-related questions of the GLFS-25 (questions, 1-4): subjects with a score of ≥3 points were classified as having "pain", with those with a score ≤2 points as having "no pain". The correlation between the change in lower limb strength and average daily step count was evaluated. All data were analysed using JMP Pro 13.1.0 (SAS Inc., USA), with the significance level set as 5%.

Ethical clearance

This study was approved by the Human Research Ethics Committee of the School of Rehabilitation Sciences, Health Sciences University of Hokkaido (authorisation number 18R083079).

Results

The study group included 11 women and 3 men aged 78.6±5.2 years. The physical function measures, obtained before and after the exercise intervention, are reported in Table 1. Grip strength and BMI remained unchanged. The CS-30 provided a good indicator of lower limb strength and increased, on average, by 130%. The Kihon checklist was also significantly improved. The GLFS-25 score improved significantly, with specific improvement on the following 4 (of the 25) questions: “To what extent do you have daily pain with movement?” (the score changed from 0.79 to 0.36; $t(13)=-2.48$, $p=0.03$), “To what extent do you have difficulty going up and down stairs?” (likewise from 0.92 to 0.29; $t(13)=-3.23$, $p<0.01$), “To what extent do you have difficulty with brisk walking?” (from 1.07 to 0.71; $t(13)=-2.69$, $p=0.02$), and “How far can you walk without rest?” (from 1.21 to 0.57; $t(13)=-2.85$, $p=0.01$). Subjective assessment of physical function capacity was also improved for the following items: “When I lost my balance on a slippery road, I was able to manage not to fall". "I used to lag behind my son while walking, but now I am comfortable walking with my son and can keep up". "I used to get tired when I climb the stairs at the station, but now I am able to keep climbing at the same speed from beginning to end". "I had little appetite but now, I really enjoy my food especially, after the exercise". "I will miss the opportunity to exercise with my friends in this group, but will try to continue exercising by myself because I realise the important effect of the programme".

Table 1. Physical function measured before and after the exercise intervention

	Before	After	t/S	df	P
Age (years)	78.6±5.2	-	-	-	-
Number of male	3	-	-	-	-
BMI (kg/m^{2})	24.6±4.7	24.3±4.3	-1.3	13	0.22
CS-30 (s)	14.8±3.5	19.0±4.3	6.9	13	<0.001
Grip strength (kg)	21.4±8.0	21.4±6.0	0.0	13	0.99
Gait speed (m/s)	1.2±0.3	1.3±0.2	2.5	13	0.03
Kihon checklist (score)	5.2±3.3	4.2±3.3	-2.5	13	0.02
GLFS-25 (score)	13.6±12.9	8.1±7.5	-39.5	-	0.01
2 step test	1.09±0.2	1.16±0.2	31.5	-	0.05

The main outcome of our study was comparison of the average daily step count between the 2018 snowy season (without prior exercise intervention: 4843±1801 steps) and the step count in 2019 (after the exercise intervention: 5738±2121 steps). The average daily step counts of our study group in 2018 ($t=2.7$, $df=13$, $p=0.02$) were significantly increased in 2019, with an average overall increase of 120% (Fig. 2). After stratification by initial grip strength, the effect of the exercise intervention on the CS-30 and average daily step count was greater for the low than for the high grip strength group (Table 2). Similarly, after stratification by the average daily step count prior to the intervention, the daily step counts improved only for subjects in the low step count group (Table 3). After stratification for pain, the CS-30 improved in both groups after the intervention, with a significant improvement in the average daily step count achieved in the "no pain" group (Table 4). Increase in lower limb strength correlated positively to the increase in the average daily step count, although this correlation was not significant ($r=0.43$, $p=0.13$).

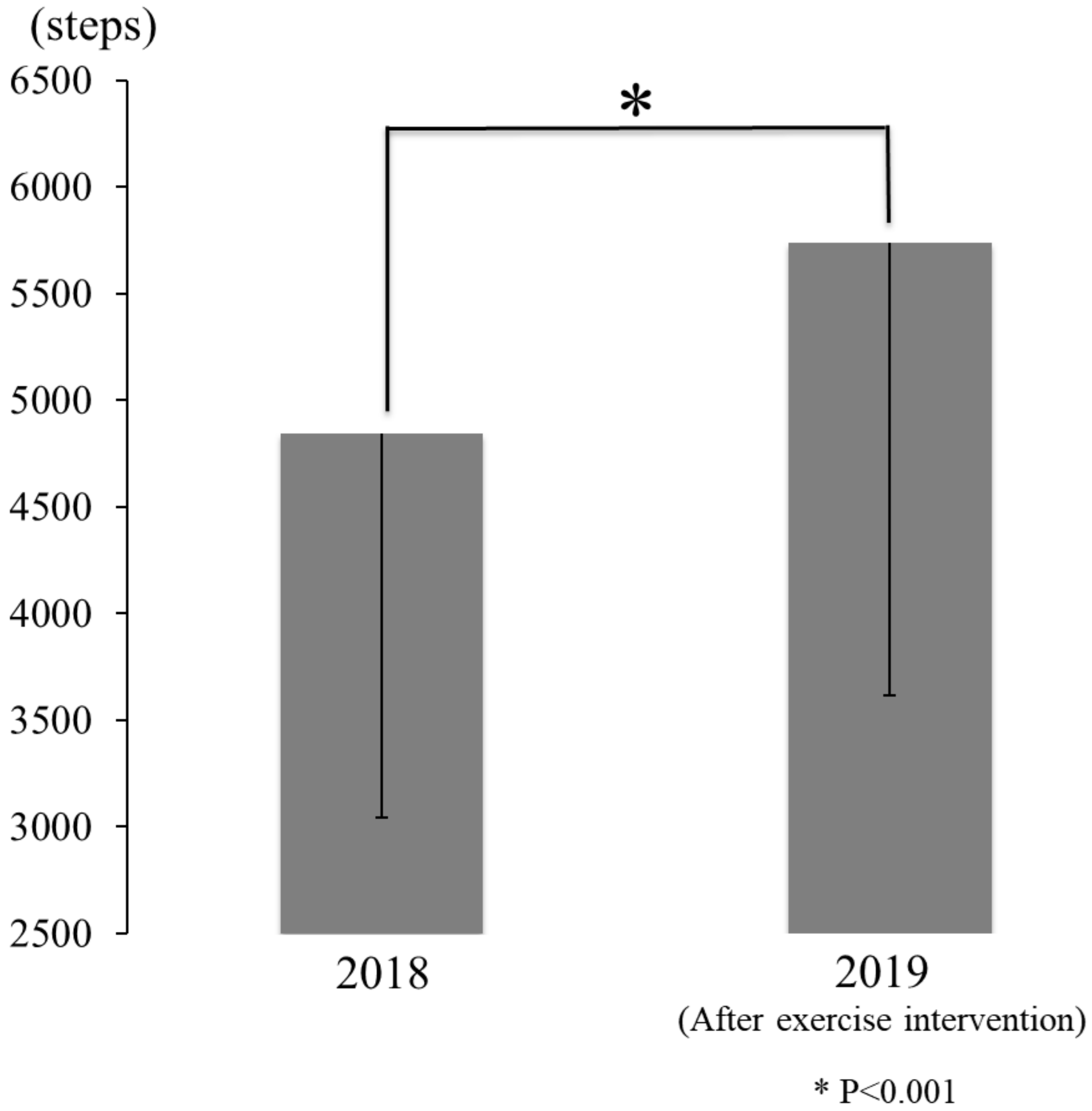

Figure 2. Comparison of daily step counts in snowy season without exercise intervention (2018) and after exercise intervention (2019)

Table 2. Effect of the lower limb strength training intervention, stratified by initial grip strength

	Low grip strength (N=7)					Normal grip strength (N=7)				
	Pre	Post	t	df	P	Pre	Post	t	df	P
CS-30 (score)	13.9 (2.4)	19 (3.4)	6	6	<.001	15.7 (4.4)	19 (5.3)	3.7	6	0.01
Daily step (count)	4628 (1310)	6243 (1620)	4.15	6	<.001	5058 (2281)	5232 (2554)	0.43	6	0.68

Note: Low grip strength was defined as <26 kg for men and <18 kg for women. Bracketed numbers in the table show standard deviation.

Table 3. Effect of the lower limb strength training intervention, stratified by daily step counts measured in 2018

	Low steps (N=7)					**High steps (N=7)**				
	Pre	Post	t	df	P	Pre	Post	t	df	P
CS-30 (score)	13.3 (2.6)	17.3 (3.6)	4.32	6	<.001	16.3 (3.9)	20.7 (4.5)	5.1	6	<.001
Daily step (count)	3483 (824)	4837 (1903)	3.01	6	0.02	6204 (1424)	6638 (2058)	0.93	6	0.39

Note: The low-step group was defined as <4746 steps (based on the average step count of elderly individuals in Japan). Bracketed numbers in the table show standard deviation.

Table 4. Effect of the lower limb strength training intervention, stratified by body pain

	With pain (N=6)					**Without pain (N=8)**				
	Pre	Post	t	df	P	Pre	Post	t	df	P
CS-30 (score)	15.3 (1.8)	18.8 (10)	4.87	5	<.001	14.3 (4.5)	19.1 (5.8)	5.16	7	<.001
Daily step (count)	4861 (1335)	5797 (2125)	1.41	5	0.22	4830 (2180)	5694 (2263)	2.38	7	0.05

Note: The presence of body pain was defined as a score of ≥3 points on the 4 pain-related questions of the GLFS-25. Bracketed numbers in the table show standard deviation.

Discussion

Improved measures of physical function, such as lower limb muscular strength indicated by CS-30, arising from our muscle strength training programme significantly improved the average daily step count during the subsequent snowy season, compared to step counts obtained during the snowy season 1 year prior (without an exercise intervention). Previously reported average daily step counts, determined nationally in Japan for individuals aged ≥70 years, in 2016, were as follows: 4746±3535 steps, overall; 5219±3728 steps for men and 4368±3327 steps for women (Ministry of Health, Labour and Welfare, Japan. 2016). The average step counts in the study group in 2018 were comparable to those of the national 2016 average. The health promotion benefits of strength training for the prevention and treatment of lifestyle diseases and improvement of physical function (including improving low back and knee pain) are well-known (Garber et al. 2011; Hayden et al. 2005; Simic et al. 2015). The current findings indicate that strength training can also improve physical activity, particularly during the snowy season. This is reasonable because people have to push the snow covering the road surface while walking outside. Moreover, to avoid slipping on icy road, stronger muscle is required during hip flexion/extension (Nagaoka et al. 2009). The direct benefit of the intervention is supported by the significant improvement identified on the items related to walking and movement of the GLFS-25. This is a reasonable anticipated outcome, which confirms previous findings of the importance of physical activity promotion (Iwaya et al. 2017). As the weather influences physical activity, the author confirmed that the weather condition was not remarkably different between the 2018 and 2019 winter seasons, with an average cumulative snowfall of 32 cm and 35 cm, respectively, and temperatures of -5.8°C and -8.9°C, respectively, measured in Shinshinotsu, the nearest meteorological point from the study site. The findings according to the result confirm that lower limb strengthening can enhance physical activity among elderly individuals, as previously reported (Hasegawa et al. 2018).

The relationship between improved lower limb strength and increased step count, however, was not a simple linear relationship. As shown in Table 2, the improvement in lower limb muscle strength (CS-30) and step count was greater for individuals in the low than in the high grip strength group, where grip strength was measured prior to the intervention. Similarly, as shown in Table 3, although the CS-30 and daily step count improved overall, the daily step count improved significantly only among subjects in the low step count group at baseline. This indicates that greater effectiveness of the exercise intervention can be expected among elderly individuals with lower baseline physical function. This finding may assist in identifying individuals who should be targeted for an exercise intervention. Of note was the further finding of smaller improvements in strength among subjects who experience daily pain compared to those without pain (Table 3). Moreover, the increase in daily step count did not reach significance among subjects with pain. Future studies with larger study groups are warranted to support multiple factor analysis to identify factors predictive of the effectiveness of a strength training programme in increasing daily step count among community-dwelling elderly individuals.

The comparison of the average daily step counts between the snowy season of 2018 and 2019 was based on the premise that the exercise intervention would improve lower limb muscle strength. The conducted 60-min structured intervention, performed twice in a week for 12 weeks, was comparable to a previously used programme (Kim et al. 2012; Kim et al. 2013) and produced comparable benefits on normal gait speed and lower limb strength. The previous programme used moderate-intensity resistance training, but low-intensity and slow movement resistance exercise was applied for the intervention. Continuous muscle contraction induces high intramuscular pressure which restricts blood flow into the muscle; thus, similar effect of exercise on vascular occlusion can be obtained. The effect of low-intensity resistance exercise was confirmed by improvement of lower limb muscle strength and normal gait speed that are well known as indices of physical function of the elderly. The current findings of a greater benefit of exercise among subjects with lower baseline strength is important from a public health perspective, as these individuals are considered at a high risk for poor health conditions (Celis-Morales et al. 2018). This is a crucial finding which might have practical implications for the design of long-term health promotion programmes among community-dwelling elderly individuals. The findings indicate that pain control may optimise improvement in lower limb strength (as measured by the CS-30). Further research is needed to translate these findings to practice.

A contribution of moderate-to-vigorous physical activity to better health outcomes has been acknowledged. On the contrary, the importance of activities of daily living, such as sitting, standing, and walking, is also recognised in terms of energy expenditure (Levine et al. 2000). As previously reported by the author's research group (Hasegawa et al. 2018), walking outside in the snowy season requires greater muscle strength and hence, the accumulation of both indoor and outdoor physical activities is important. There is evidence that overall physical activity declines among home-dwelling elderly individuals in winter, compared to that in autumn, with this seasonal effect being greater among individuals living in colder temperatures (Hayashi et al. 2017). An issue to consider, which is specific to Japan, is the effect of partial heating systems that are common and may further limit indoor physical activity levels during the winter; however, the author did not include subjects' living environment in the assessment. Regardless of the season, physical activity level is inversely associated to feelings of fatigue, with fatigue levels predisposing to sedentary behaviour (Engberg et al. 2017). Furthermore, nonagenarians who experience less fatigue have a longer life expectancy and greater muscle strength (Mänty et al. 2014). Therefore, improvement in muscle strength could be effective in reducing subjective fatigue, as well as ameliorating physical activity capacity.

Although the importance of increasing physical activity among elderly individuals is well-known, a practical method to promote physical activity among this segment of the population is not straightforward. The results do show that a structured, 60-min programme of muscle strengthening, performed two times per week, over the three months before the winter season, was effective in enhancing physical activity among elderly individuals during the snowy months. As such, the author believes that the intervention could provide an effective model of intervention to lower the risk of physical activity decline among community-dwelling elderly individuals living in snowy regions. As it is necessary to provide valid measures to justify interventions to improve the overall health standard of elderly individuals, further clarification of the parameters of the programme is needed, such as the optimal duration of strengthening programme for physical activity promotion, as well as determining the most practical way to improve muscle strength among community-dwelling elderly people.

Notably, this study has small sample size, with only 19 of the original 35 subjects willing to participate, of which only 14 had completed the 3-month exercise programme. Therefore, there is a need to further examine factors associated with exercise adherence among elderly individuals. Recently, a national health promotion strategy has been adopted in Japan to enhance physical activity among elderly individuals through the creation of community-based programmes that promote fun physical activity and provide an opportunity for social interaction. However, considering the importance the author identified in enhancing lower limb muscle strength over a specific time-period (i.e., 3 months prior to winter in our study), instructor direction/supervision might be beneficial in prevention strategies. An appropriate training stimulus must be also considered, including the type of exercise, as well as the intensity, duration, and number of repetitions.

In the current study, some individuals reported exercising at home but not to the extent that they felt fatigue. As it is unrealistic that experts can be available to supervise all exercise interventions, there is a need to identify factors that can enhance the effectiveness of home-based programmes. This would also be important considering other factors that can impede participation in an exercise programme, such as the distance from the venue, inconvenience, and expenses of transportation and time restrictions.

Training community-based elderly individuals to act as “instructors” (known as train the trainer model) could provide a practical and effective solution. Several train the trainer models already exist in Japan. For example, elderly individuals have been trained to perform frailty checks among local residents in Kashiwa City, acting as “Kashiwa frailty prevention supporter”. In the Ibaraki prefecture, the “Silver rehabilitation exercise” programme trained exercise instructors among community residents. Yamada et al. (2017) also reported that educated volunteer staff encouraged effective self-management exercise groups. Once these projects are well recognised by community residents, they tend to become rooted within the community and sustained. Collaboration with college programmes in training students in exercise prescription might also provide an opportunity for the development of a sustainable community-based programme of exercise for elderly individuals.

The present study has the following limitations. First, the sample size was small; however, novel findings were obtained with appropriate statistical analysis. Second, possible factors related to a level of physical activity such as social/psychological factors and environment factors including public transport were not considered. Further research is desired with a large sample size to also analyse other related factors mentioned above. Third, in this study, only daily step counts represented a level of physical activity. Activity intensity and sedentary behaviour should be considered to clarify the effect of improved lower muscle strength.

Conclusion

The author described a 60-min exercise programme, performed 2×/week, which was effective in the improvement of lower limb muscle strength which, in turn, positively correlated with an increase in physical activity during the winter months, measured using the daily step count. Future research is needed to identify factors that can enhance adherence to a home- and community-based exercise programme.

III. Verification of seasonal frailty among community-dwelling elderly living in snowy cold regions

Aim of the study

Seasonal fluctuation of frailty might be an indicator of the seriousness of the condition; specifically, in a progression of frailty, older adults first tend to decrease their amount of physical activity in the snowy season, after which point they will continue to become progressively frailer regardless of the season. The author named this study the ‘seasonal frailty hypothesis’, aiming to verify the present criteria of seasonal frailty and its association with health-related quality of life.

Methods

Participants were community-dwelling elderly aged 65 years or older who regularly attended community-based senior activities in Tobetsu town, northern Japan. People who had a certificate needed long-term care insurance which is run by municipal governments to provide long-term care services were excluded.

The current research was conducted by distributing questionnaire twice: in the snowy season and non-snowy season. 260 questionnaire forms for snowy season were distributed to senior club members from January to February 2019. 181 out of 260 questionnaire forms were collected by mail. 178 questionnaires for non-snowy season were sent in May 2019 because three of 181 were missing physical address data. The status of frailty was judged according to the Kihon checklist (KCL). The KCL, which was developed by the Japanese Ministry of Health, Labour and Welfare, was selected to assess the status of frailty (Satake et al. 2017; Sewo et al. 2016). It consists of 25 Yes/No questions, and the scoring ranges from 0 to 25. A cut-off point of ≥8 is considered sufficient to indicate frailty, and 4-7 is considered a pre-frailty condition (Satake et al. 2017). The test also comprises seven categorised representing domains: (1) activities of daily living, (2) physical strength, (3) nutrition, (4) oral function, (5) isolation, (6) cognitive decline, and (7) depressive mood. These sub-domains allow for a better understanding of primary features and manifestations of frailty. Based on an original classification reported by Satake et al. (2017), a score of 4-7 points constitutes a condition of pre-frailty; however, in the current study, a point of ≥4 was considered frailty, since our study targeted the transitional period from robust to frailty. Social frailty was judged according to the method of Makizako et al. (2015), which consisted of five questions concerning the following scenarios: (1) living alone, (2) going out less frequently compared with the prior year, (3) hardly visiting friends, (4) feeling not helpful to friends or family, and (5) having no opportunity to talk with someone every day. Social frailty was judged when confirming more than two questions among the above five. Several questionnaires were not completely filled out, but, when it was possible to ascertain a cut-off point, the reply was regarded as valid. Self-rated health, life satisfaction, sense of ability to undertake daily exercise (exercise satisfaction) and QOL score calculated by Japanese version EQ-5D-5L (Ikeda et al. 2015) were also investigated.

Statistical analysis

According to the status of frailty in both snowy/non-snowy seasons, the following four groups were identified; Robust (robust/robust), non-snowy frailty (robust/frailty), snowy frailty (frailty/robust), year-long frailty (frailty/frailty). To examine the risk factors for year-long frailty group, a stepwise regression method was used to narrow down the key contributing factors. The following variables were used to derive a multiple regression equation: sex, age (65-69, 70-74, 75-79, 80-84, ≥85), the presence of any family member living together, performance within the five sub-domain categories of frailty (low physical strength, low oral function, poor standard of activities of daily living, cognitive decline, and depressive mood), social frailty, life satisfaction, self-rated health, exercise satisfaction, and the presence of three or more medication types. All factors (excluding sex, age and presence of family living together) were used for both snowy/non-snowy seasons, and established as candidate for contributing factors. All of them were categorical variables.

As a precondition for investigating the association between frailty and health-related quality of life, the correlation of KCL (which served the basis of an appraisal of frailty) and QOL score was confirmed. For the purpose of this correlation analysis, the average scores for snowy/non-snowy season was used for both KCL and QOL score. A one-way analysis of variance (ANOVA) was followed by a multiple comparisons test using the status of frailty among the four identified groups. In addition, in order to compare the strength of the influence of the KCL scores in both snowy/non-snowy seasons on the QOL score, a multiple regression equation was generated in which the QOL score was set as the outcome variable, and the KCL score in snowy/non-snowy seasons, sex and age were the designated independent variables.

Ethical clearance

This study was approved by the Human Research Ethics Committee of the School of Rehabilitation Sciences, Health Sciences University of Hokkaido (authorisation number 18R090084).

Results

A total of 181 questionnaires were collected for the snowy season, of which three had missing physical address data. As a result, 178 questionnaires were sent to the same participants in the non-snowy season, and 158 were returned. Of these, 144 were able to demonstrate comparative levels of frailty in snowy/non-snowy seasons, and so could be used for analysis (Fig 1). An overview of the participants is shown in Table 1. Table 2. shows the result of assessment of frailty in both snowy/non-snowy seasons. Stepwise regression analysis was conducted by setting the frailty group (identified as frailty in both snowy/non-snowy seasons) as outcome variable. Five factors were selected as effective predictors: (1) cognitive decline, (2) mood of depression, (2) self-rated health, (4) low physical strength, and (5) social frailty during the non-snow season (Table 3). The multiple regression equation derived by these five predictors was a significantly predictive formula (R^2 =0.48).

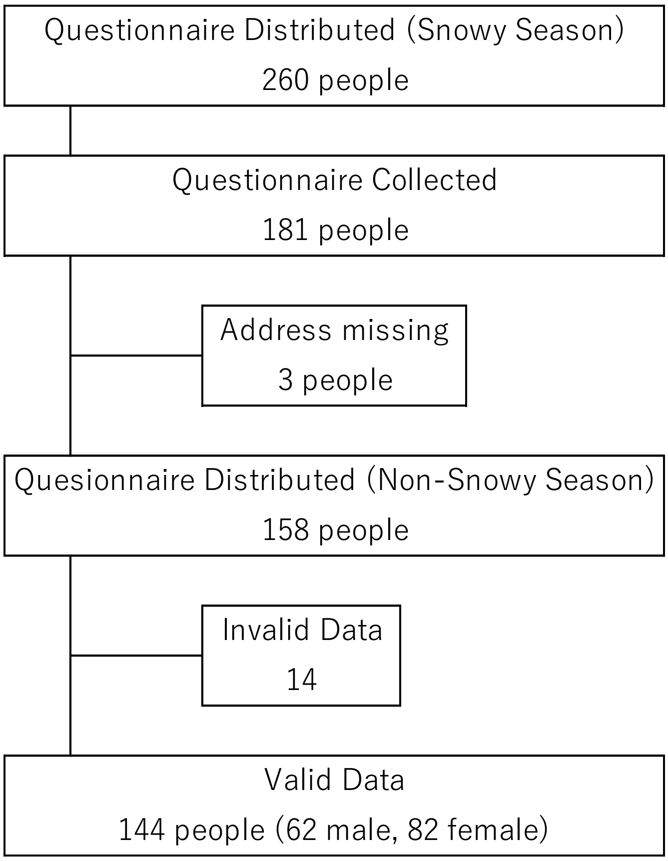

Figure 1. Questionnaire distribution/collection flow chart

Table 1. Characteristics of all respondent of the questionnaire (N=144)

		Snowy season		Non-snowy season	
Category		No.	%	No.	%
Sex	Male	62	43		
	Female	82	57		
Age (years)	65-69	12	8		
	70-74	27	19		
	75-59	50	35		
	80-84	38	26		
	85<	17	12		
Life satisfaction	Sartisfied	129	90	127	88
	Not sartisfied	15	10	17	12
Self-rated health	Healthy	110	76	107	74
	Not healthy	34	24	37	26
Exercise satisfaction	Sartisfied	35	24	32	22
	Not sartisfied	109	76	112	78
Frailty	Robust	64	44	61	43
	Pre-frailty	53	37	48	33
	Frailty	27	19	35	24
Sub-domain of frailty	Low physical strength	37	26	30	21
	Low nutrition	2	1	3	2
	Low oral function	34	24	35	24
	Poor activity of daily living	4	3	7	5
	Cognitive decline	53	37	45	31
	Mood of depression	31	22	41	28
Social Frailty	Robust	112	78	118	82
	Frailty	28	19	25	17
	Unable to judge	4	3	1	1
Average QOL score (SD)		0.83 (0.14)		0.83 (0.15)	
Average KCL score (SD)		4.6 (3.55)		5.09 (4.00)	

Table 2. Status of frailty in snowy/non-snowy seasons

Snowy \ Non-snowy	Frailty	Robust
Frailty	65 (45)	16 (11)
Robust	18 (13)	45 (31)

(%)

Table 3. Significant predictors of "Frailty throughout year"

	Fraily	
Predictor	β-coefficient	P
Cognitive decline (non-snowy season)	0.28	<.0001
Mood of depression (non-snowy season)	0.24	<.0001
Self-rated health (non-snowy season)	0.22	<.001
Low physical strength (non-snowy season)	0.21	<.001
Social frailty (non-snowy season)	0.15	0.02

The correlation between KCL and QOL score was significant, with a negative correlation coefficient of -0.76 (P<.0001). After an examination of QOL score among four groups using ANOVA (Fig 2.), the Steel test, a nonparametric multiple comparisons test with the robust group set as control, was performed, since equal variance of each group could not be confirmed. As a result, significant decline of QOL score in non-snowy frailty group and year-long frailty group compared with robust group was observed (P=0.02, P<.0001, respectively). Table 4. shows the results of multiple regression analysis of QOL scores using KCL in each season. The R-squared of this multiple regression equation was 0.61 and a significant prediction equation of p<.0001 was obtained. It was found that the KCL score in the non-snowy season is more influential as a predictor of annual average QOL score than snowy season’s one.

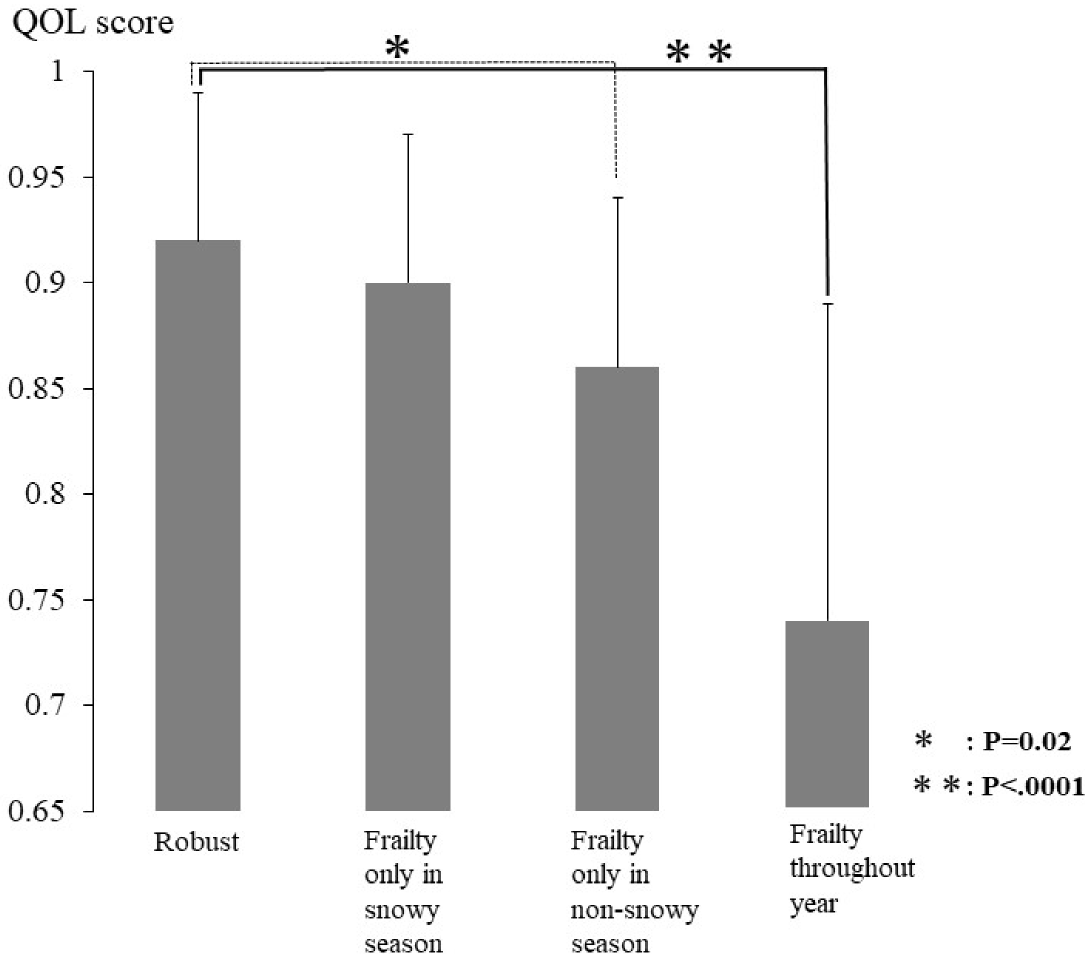

Figure 2. The comparison in QOL score among 4 different seasonal status in frailty

Table 4. Significant predictors of average QOL score (Snowy/Non-snowy seasons)

	QOL score	
Predictor	β-coefficient	P
KCL in non-snowy season	-0.61	<.0001
KCL in snowy season	-0.20	0.02
Age 80-84	-0.16	0.09
Age 70-74	-0.14	0.11
Age ≥85	-0.09	0.24
Age75-79	-0.11	0.26
Female	-0.01	0.85

Discussion

One of the main aims of this study was to confirm whether the status of frailty fluctuated depending on the season. Most of the participants were classified in the robust group or the year-long frailty group; however, the existence of frail elderly in either snowy or non-snowy seasons was confirmed, nearly 10%. From the comparison of QOL scores among these four groups, the highest score was generated from the robust group, the lowest score from year-long frailty group, and the median average score from the seasonal frailty (frailty only in snowy or non-snowy season) group. Since the QOL score reflects a subject's health status, seasonal frailty was qualitatively placed in-between year-long frailty and robustness. Figure 3, which is a modified version of Kuzuya's report (Kuzuya M. 2009), schematically shows this.

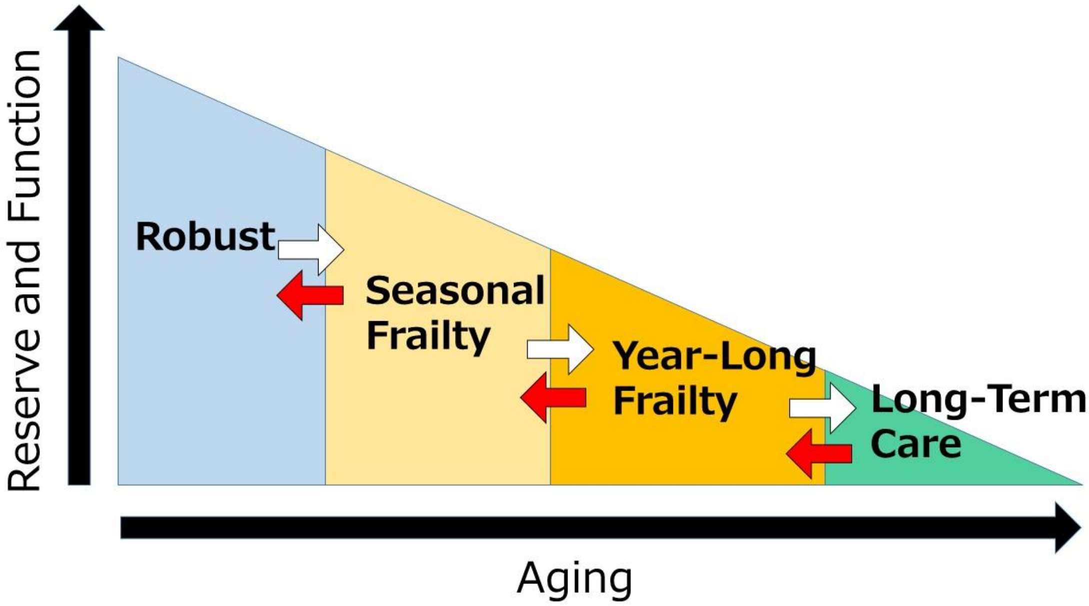

Figure 3. Schematic diagram indicating the concept of seasonal frailty

In creating a prediction model for year-long frailty, cognitive decline, depressive mood, self-rated health, low physical function, and social frailty in the non-snowy season were selected as predictive factors. Hypothetically, the author thought that the snowy season frailty followed the year-long robust condition. It was further assumed that, subsequently, year-long frailty would be developed. The discovery that the sub-domain of frailty in the non-snowy season could be established as a predictor of year-long frailty supports this hypothesis. Although winter storms and cold make even a robust person living independently reduce the frequency of his or her outings, elderly who strengthened their lower limb muscles by means of three months of structured and supervised exercise and significantly increased their daily steps from the previous year despite the progress of aging as discussed in Chapter Ⅲ. Previous research has shown that there is a significant correlation between daily steps and lower limb muscle strength during the snowy season (Hasegawa et al. 2018). Put another way, lower limb muscle strength is one of the factors of ensuring adequate activity during the snowy season. It is possible that physical activity during the snowy season declines, resulting in a corresponding decrease of muscle strength. On the other hand, in the same previous study, no significant correlation was confirmed between lower limb muscle strength and daily steps during the non-snowy season. Thus, it can be interpreted that even if lower limb muscle strength has somewhat declined, people are able to be active (given good road conditions) in non-snowy season. However, with strength declining below a certain level, physical activity even in non-snowy season gradually decreases, in addition to the inactivity during the snowy season. Therefore, it can be concluded that the condition of frailty in the non-snowy season is a more pronounced status of diminished physical ability than frailty during the snowy season. The same conclusion can be drawn from the result of a multiple regression equation that predicted QOL score. Better health status indicated by lower KCL score contributed to the increase in the average QOL score for both seasons.

Careful consideration should be given to preventive care and the promotion of healthy activities with this understanding that frailty varies seasonally (in snowy and cold regions, in particular), and that the decline in health during the non-snowy season is a stronger indicator of increasing frailty. In Japan, in a project of long-term care prevention, the KCL used in the current study is used as a tool to detect persons who are eligible for the secondary prevention programme. What is suggested from the current study is that the results of these assessments are influenced by the season in which they are administered. Regarding the comprehensive health assessment using KCL, a recommended time frame for reassessment is not specified; however, it should be considered that season affects the results of these assessments in snowy and cold regions.

The discussion has focused on frailty during the snowy season as well as year-long frailty. The study confirmed the existence of people with frailty only in the non-snowy season. One of the possible reasons could be the physical exercise required for snow removal in the snowy season. Snow removal work is an additional physical activity unique to the snowy season, especially in the case of an individual living in a detached house in snowy and cold regions. It is reported that ‘shovelling snow by hand' corresponds to an exercise intensity of 6 times of at rest; 6 metabolic equivalents (METs) (Ainsworth et al. 1993). Therefore, shovelling can be a possible factor in maintaining physical activity during the snowy season. Especially in cases where there are no established habits of physical activity during non-snowy season, if it is necessary to remove snow during snowy season, it is reasonable that frailty be exhibited only in non-snowy season. This phenomenon is contrary to the hypotheses, hence it is essential for future research to investigate the condition of frailty only in non-snowy season, as no information was obtained from the current study specifically regarding the presence of physical activity in different seasons as well as how unique physical activities contribute to a meaningful measure of physical function.

The current study has some limitations. First, the small sample size was used to estimate the prevalence of frailty depends on season (robust/snowy frailty/non-snowy frailty/year-long frailty); nevertheless, the existence of seasonal frailty was confirmed, and reference values for further research were calculated. Second, no objective physical indicator was obtained, with physical function rather inferred from the KCL score. Third, the unexpected phenomenon of non-snowy frailty is yet uncomprehended.

Conclusion

It is suggested that the extent of the condition of frailty fluctuates seasonally, even within the same individual. Furthermore, it is proposed that such person occupies an intermediate position between advanced frailty and robustness. Frailty in the non-snowy season is considered to be closer to a condition that has progressed to physical dysfunction.

Key Findings

In Chapter Ⅰ, the author confirmed that physical activeness in snowy season generally declines. The difference in lower limb muscle strength between people whose physical activity is maintained and people whose physical activity decline was revealed. In Chapter Ⅱ, lower limb muscle strength was intentionally increased to examine the effect on physical activity in the snowy season. As a result, it was improved compared to the previous year (without any exercise intervention) despite the progress of aging for one year. The author has derived seasonal frailty hypothesis shown in Fig 1 in Chapter Ⅰ. The existence of seasonal frailty was confirmed in Chapter Ⅲ, and it was inferred that the status of frailty is affected from robust to snowy frailty, consequently transferred to a year-long frailty.

General Discussion

In this study, the author revealed that the physical activity decreased during the snowy season, but the physical activity could be maintained/improved by strengthening muscle strength. In exercise interventions for lower limb muscle strengthening, the effects of intervention differ depending on the presence of pain and the individual's physical function. This exercise intervention incorporated low-intensity resistance exercise, which is considered to be unlikely to affect hemodynamics, and was able to confirm its effect. In Chapter III, the practical method in which local people can participate widely and provide sustainable exercise opportunities was also discussed. Although actual challenges remain to be solved, the author was able to narrow down the necessary assessment items such as pain and physical function of the individual, and the use of low-intensity resistance exercise.

The author would describe two strength of the current study. First one is that the seasonal frailty hypothesis has been derived and this phenomenon has been confirmed. The fact starting with the signs of inactivity in snowy season and continued inactivity after the thaw as a next step might be known empirically by everyone who lives in the community, however, the study proved the phenomenon scientifically and focused on it as a key to early prevention of frailty. In addition, the findings from the study were important because practical consideration can be provided in implementing care preventive measures in the snowy-cold regions in order to create cost-effective measures with limited human resources and fund.

Secondly, the effect of muscle strengthening by three months exercise programme and subsequent improvement in physical activity in the snowy season was confirmed in Chapter Ⅲ. The center of the exercise programme was a low-intensity resistance training whose effect has been reported (Tanimoto and Ishii. 2005), however, it was meaningful to verify that the exercise intervention was effective not only for muscle strengthening but also in improving physical activity as estimated in Chapter Ⅱ. As discussed in Chapter Ⅱ and Ⅲ, higher muscle strength contributes the promotion of physical activity in the snowy season. Moreover, it also induces the effect of fatigue improvement which propels older people to be active. The great benefits of muscle strengthening for health promotion of elderly people were confirmed and the author obtained some tips to promote preventive care.

As a future perspective, development of a practical method is required in order to implement the findings obtained from the study to community dwelling elderly people. The “train the trainer model” discussed in Chapter Ⅲ is specific example. There are several issues to be considered for sustainability, such as human resources, funds, or concrete method to train the trainers, however, enhancing the adherence to physically active life based on the finding from the study will be the way to success.

Conclusion

Among older people living in the snowy cold regions, it was suggested that seasonal fluctuation affect their physical activity and overall health. The facts obtained were: Lower limb muscle strength is one of the key factors to maintain physical activity in the snowy season; the status of seasonal frailty emerges in transitional period from robust to year-long (advanced) frailty; and being frail in the non-snowy season is closely related to year-long frailty. The influence of the snowfall season, which accounts for half of the year cannot be ignored. The practical knowledge to take a preventive measure of long-term care for the elderly living in the snowy-cold regions was obtained.

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List of Archives

Publications

Hasegawa J, Ito MY, Yamauchi T (2017) Development of screening tool to predict malnutrition among children under two years old in Zambia. Global Health Action. 10(1):1339981

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