学位論文の要約

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学位論文題名

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）

1. 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. 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. Little has been reported about the relationship between physical capacity or function and physical activity. It is 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. 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. However, if muscle strength is a key underlying component of physical activity, 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. 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.

2. 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 1, the difference in the association between physical activity and lower limb muscle in both snowy season and non-snowy season is discussed. In Chapter 2, 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 3, the author confirms the phenomenon of "seasonal frailty", and investigates the association between the status of frailty and health-related quality of life.

3. Impact of season on the association between muscle strength/volume and physical activity among community-dwelling elderly people living in snowy-cold regions* (Chapter 1)

Objectives:

To clarify the association between physical activity levels and muscle strength/skeletal muscle mass during non-snowy and snowy seasons in northern Japan.

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.

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.

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*Chapter 1 modified the original article published on Journal of Physiological Anthropology. 2018; 37:1-6.

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.

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.

4. Effect of a lower limb strength training programme on physical activity during the snowy season among community-dwelling elderly individuals** (Chapter 2)

Objectives:
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.

Methods:
Participants were same as Chapter 1. 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. Low-intensity resistance exercises were used, performed at a low velocity. 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.

** Chapter Ⅱ modified the original article published on Annals of Human Biology. 2019; https://doi.org/10.1080/03014460.2019.1641222

Results:
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.

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.

5. Verification of seasonal frailty among community-dwelling elderly living in snowy cold regions (Chapter 3)

Objectives:
To clarify the phenomenon of seasonal frailty and its association with health-related quality of life.

Methods:
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 $4 \leq$ of KCL score.

Results:
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.

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.

6. Key Findings

In Chapter 1, 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 2, 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.

The existence of seasonal frailty was confirmed in Chapter 3, and it was inferred that the status of frailty is affected from robust to snowy frailty, consequently transferred to a year-long frailty.

7. General 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.