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Relationship between Nonexercise Activity Thermogenesis and Calf Circumference in Older Women

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Abstract

Purpose: Frailty is a state of declined vitality of the body and mind with age in which life functions are impaired. In addition, there is a difference in the susceptibility of older women to frailty compared with that of older men. Therefore, assessing and encouraging physical activity in older adults before they become frail is essential. We aimed to clarify the relationship between calf circumference and body composition and assess the potential association between calf circumference and physical activity indices in older women. **Methods:** This cross-sectional study included 18 healthy older adults (age 69.0 ± 5.7 years). The physical characteristics, calf circumference, body composition, calf muscle thickness, and physical activity questionnaire that included items on exercise-related activity thermogenesis (EAT) and nonexercise activity thermogenesis (NEAT) were assessed. The association between calf circumference and these additional measures was examined. **Results:** Positive and significant correlations were found between the calf circumference and body weight, body mass index (BMI), skeletal muscle mass, skeletal muscle mass index, calf muscle thickness, total questionnaire score, and NEAT score (r = 0.66 - 0.87). However, no significant correlations were observed between the calf circumference and EAT scores. **Conclusion:** Calf circumference in older women may reflect NEAT activity. Improving NEAT activity is an important health-promoting factor in older women.

Keywords

Nonexercise Activity Thermogenesis, Frailty, Calf Circumference, Older Women

1. Introduction

Frailty is a state of declined vitality of the body and mind (physical and cognitive functions) with age and life functions being impaired [1]. Physical and mental frailty emerges in many older adults [2], resulting in serious consequences, such as reduced quality of life, falls, use of medical facilities, hospital admissions, and mortality [3]-[5]. Fried *et al.* defined five criteria for frailty: unintentional weight loss, self-reported exhaustion, weakness (grip strength), slow walking speed, and low physical activity [6]. If left untreated, frailty can progress into a vicious cycle of reduced activity, resulting in reduced general endurance, fatigue, and, in turn, reduced physical activity.

One factor contributing to this reduction in activity level is a decrease in whole-body muscle mass. The loss of skeletal muscle mass and strength that occurs with advancing age is defined as sarcopenia [7]. According to sarcopenia guidelines, a healthy diet and physical activity are strongly recommended [8] [9]. In Japan, the proportion of adults aged ≥ 65 years is increasing and may rise further to 39.9% by 2060 [10]. In addition, there is a difference in the susceptibility of older women to frailty compared with that of older men [11]. Therefore, assessing and encouraging physical activity in older adults before they become frail is essential.

Magnetic resonance imaging is the gold standard for measuring whole-body muscle mass but is often only available in research settings and cannot be easily used in clinical settings. Therefore, calf circumference measurements are used as an alternative screening method [12]-[15]. Some studies have found a positive correlation between calf circumference and calf muscle thickness and volume and a negative correlation with subcutaneous fat [15] [16]. Furthermore, calf circumference is positively correlated with total skeletal muscle mass [12] and maximal oxygen uptake (VO_2max) [14].

There are two methods for assessing physical activity: direct measurement using continuous heart rate or accelerometers and indirect measurement using physical activity questionnaires. The physical activity questionnaire published by Washburn *et al.* has proven reliable and valid [17] and includes items on exercise-related activity thermogenesis (EAT) and nonexercise activity thermogenesis (NEAT), which makes it possible to score each item. Previous studies show the energy expenditure of NEAT is much greater than that of EAT [18] [19]. However, it is unclear to what extent these physical activities influence morphological characteristics. Therefore, we aimed to determine the relationship between calf circumference and body composition, such as calf muscle thickness and total skeletal muscle mass, in community-dwelling older women and assess the potential association between calf circumference and indices of physical activity.

2. Methods

2.1. Study Design

The Cross-Sectional study was conducted among older adults in a healthy community-dwelling. These older adults participated in health classes conducted at the university and then continued as is between January and March 2021. The study was conducted in compliance with the principles of the Declaration of Helsinki, with oral and written explanations, and consent was obtained from the participants. This study was approved by the Ethics Committee of Kanazawa Orthopaedic Sports Medicine Clinic (Kanazawa-OSMC-2019-001).

The participants were healthy older adults living in a community who participated in monthly light load health classes run by a university. According to questionnaires and interviews, all participants were able to live independently and had no history of falls, fractures, malignant tumours, cerebrovascular diseases, or serious respiratory diseases within the past year. Those with a body mass index (BMI) of >25 kg/m^2 were excluded from this population, as previous studies have shown that the correlation between calf circumference and calf muscle thickness is low (r = 0.249) [20]. The measurement items were as follows:

1) Physical characteristics

The height (HP20, Tsutsumi, Japan) and weight (HA528, Tanita, Japan) were measured in the standing position, and the BMI was calculated.

2) Calf circumference

The calf circumference was measured 30% proximal to a line between the lateral malleolus of the fibula and lateral condyle of the tibia using a measuring tape in the supine position, on the bed with the ankle joint held at 90˚ and the foot planted on the wall, as described in a previous study in Japanese adults [13]. To reduce errors, the average of the values measured twice was used, and the measurements were performed by the same person.

3) Body composition

The skeletal muscle mass and body fat percentage were measured by bioelectrical impedance (InBodyS10, In Body Japan, Japan) [21]. The skeletal muscle mass index (SMI) was calculated by dividing the measured limb skeletal muscle mass by height squared. The participants were instructed to refrain from food intake for 12 h before measurements were taken. The measurements were taken between 10 and 11 am. Regarding medicines, we confirmed that they were not taking any medicines that could affect their body composition.

4) Calf muscle thickness

Measurements were performed using a B-mode ultrasound system (SSD-3500SV; Fujifilm, Japan) and a 7.5-MHz linear probe. The participants were asked to rest in a supine position on a bed with the ankle joint maintained at 90˚ and the foot planted on the wall. The measurement site was 30% proximal between the lateral malleolus of the fibula and lateral condyle of the tibia [16] [22]. The measurements were performed by the same person. Prior to the measurement, we evaluated the reliability using the test-retest method. The intraclass correlation coefficients (ICC) of the calf muscle thickness showed excellent values (ICC = 0.983).

5) Physical activity questionnaire

The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) was used; the PASIPD includes 13 questions regarding physical activity related to sports, leisure activities, housework, mobility, work, and sedentary time [17] [23]. The questionnaire uses a recall method that can be applied to answer questions about physical activity in the previous week using a list of options. Each item has the option to select the frequency (how many times per week) and duration of the activity, and each item has an exercise intensity coefficient. The score is calculated by multiplying the exercise intensity coefficient for each item by the frequency and duration of the exercise. The total score is calculated by adding all the values obtained for each question item. The score is then divided into an EAT score (light sports or recreational activities, moderate sports or recreational activities, strenuous sports or recreational activities, and increased muscle strength and endurance) and a NEAT-related score (stationary activities, walking, light household, heavy household, home repair, lawn work or yard care, outdoor gardening, care for another person, work for pay, or volunteering).

2.2. Statistical Analyses

For statistical processing, after checking the normal distribution, correlations between leg circumference and each measured item were examined using Pearson's two-tailed correlation coefficient. Graph Pad Prism ver. 6 (GraphPad, San Diego, CA) was used for statistical analyses. Statistical significance was set at $p < 0.05$. All data are presented as mean± SD.

3. Results

Eighteen healthy older women participated in this study. All participants were interviewed beforehand to ensure that they had no pre-existing orthopaedic or medical conditions that would affect the study. Two women were excluded because of missing data (questionnaire data), and eighteen older women were included in the analysis. The mean age of the participants was 69.0 ± 5.7 years. The height, weight, and BMI are presented in **Table 1**.

Table 1. Characteristics of the study participants.

Sex	N	Age (years)	Body Height (cm)	Body Mass (kg)	BMI (kg/m^2)
Women	18	69.0 ± 5.7 (61 - 84)	155.1 ± 5.5 (146.9 - 168.6)	54.3 ± 7.2 (42.0 - 66.7)	21.7 ± 2.1 (18.4 - 24.4)

Data are shown as mean ± SD. (Range) SD. BMI: Body Mass Index.

The calf circumference, calf muscle thickness, skeletal muscle mass, and SMI are shown in **Table 2**. Two participants had a calf circumference of <33 cm and an SMI of <5.7 kg/m^2, which corresponds to the sarcopenia diagnostic criteria of the Asian Sarcopenia Working Group [8]. The body fat percentage ranged from 23.7% - 38.8%.

Table 2. Anthropometric measurements and body composition measurements.

Calf circumference (cm)	Skeletal muscle mass (kg)	SMI (kg/m^2)	Calf muscle thickness (mm)
34.4 ± 2.7 (28.5 - 39.2)	19.5 ± 2.2 (15.1 - 23.9)	6.0 ± 0.5 (4.7 - 7.2)	41.7 ± 5.3 (33.4 - 51.9)

Data are shown as mean ± SD. (Range) SD. SMI: Skeletal muscle mass index.

The PASIPD scores are presented in Table 3; the total score was 15.3 ± 9.4 points. When the points were divided into EAT and NEAT-related scores according to the questionnaire items, the mean scores were 2.4 ± 3.5 and 12.9 ± 7.1 points, respectively.

The correlation between the calf circumference and each measure is shown in Figure 1. Significant positive correlations were observed between the body weight, BMI, skeletal muscle mass, SMI, calf muscle thickness, PASIPD total score, and NEAT score. However, only the EAT score in the PASIPD group did not show a significant correlation.

Table 3. Total and subcategory scores for the PASIPD

Total score (point)	EAT score (point)	NEAT score (point)
15.3 ± 9.4	2.4 ± 3.5	12.9 ± 7.1

Data are shown as mean ± SD.

4. Discussion

We investigated the relationships between calf circumference, body composition, and physical activity in older women. The results showed that the calf circumference strongly correlated with the skeletal muscle mass and muscle thickness [20]. Furthermore, the calf circumference was strongly correlated with physical activity and the NEAT scores but not with the EAT scores. These findings suggest that calf circumference is significantly associated with NEAT and that improving activities of daily living and increasing NEAT may be more effective in preventing and improving frailty than special sports activities.

Although our study participants were older adults with a nonuniform body fat percentage and included individuals who may have been diagnosed with sarcopenia, the calf leg circumference was positively correlated with the skeletal muscle mass or calf muscle thickness. Macedo *et al.* reported similar results in a previous study, supporting the calf circumference as a simple tool to measure skeletal muscle mass in older women [20]. Additionally, our results showed that the calf circumference correlated more with NEAT than with EAT. This means that increasing NEAT may lead to an increase in skeletal muscle mass and suggests that the calf circumference could be used as an assessment indicator.

The total PASIPD score was 18.4 ± 11.2 points, which was comparable to the physical activity scores of older people reported in a previous study [24]. Physical activity is classified into two categories: EAT, which is a purpose-driven

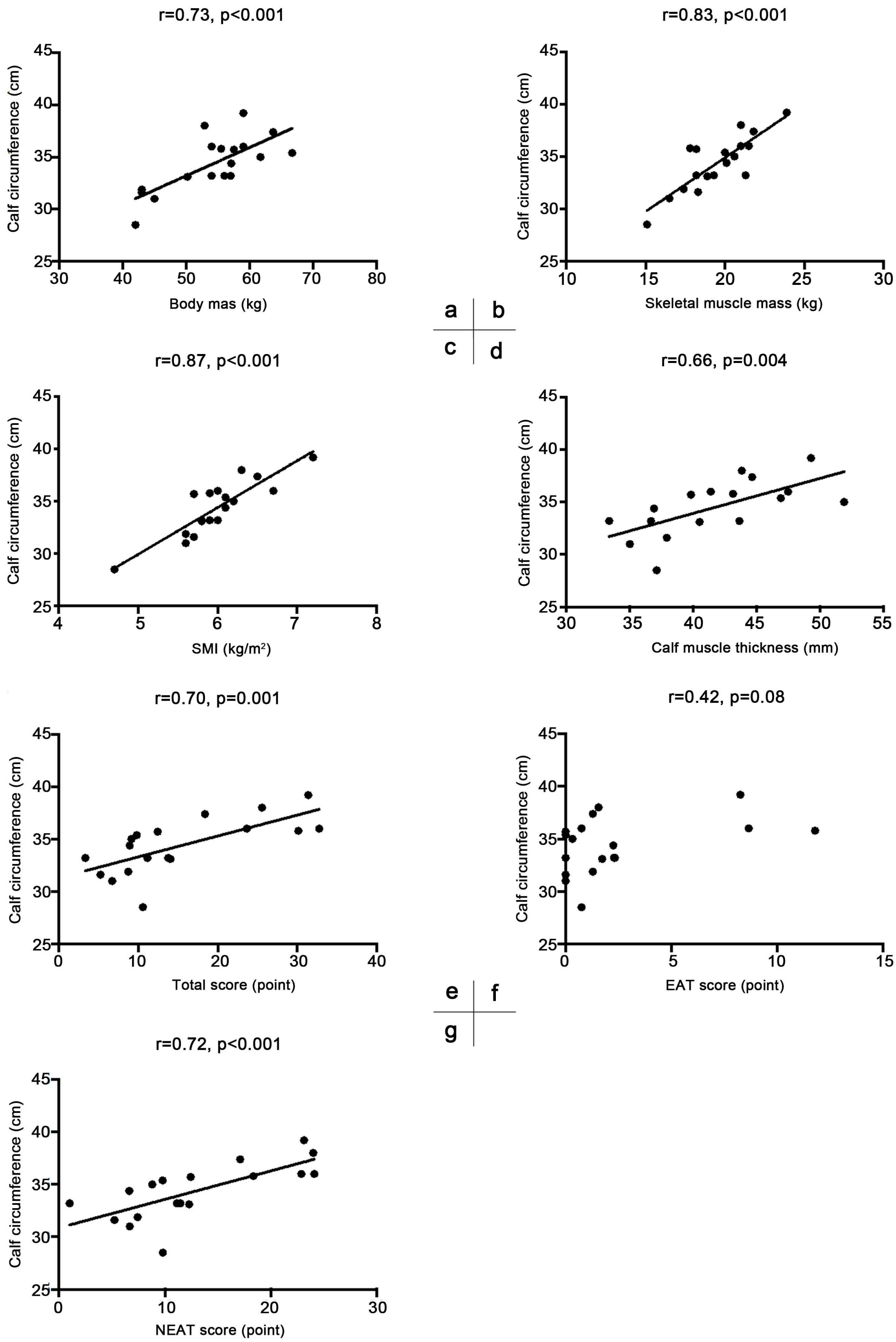

Figure 1. Association between the calf circumference and body mass (a), skeletal muscle mass (b), SMI (c), calf muscle thickness (d), total score of the PASIPD (e), NEAT score of the PASIPD (f), and EAT score of the PASIPD (g).

activity, such as that for health, fitness, or weight loss; and NEAT, which is a leisure-time activity, such as sitting, standing, walking, climbing stairs, shopping, and other activities of daily living [25]. EAT accounts for only 15% - 30% of total energy expenditure, even in adults who exercise regularly [26] [27]. Additionally, only approximately 5% of adults in developed countries exercise habitually [28]. NEAT, on the other hand, ranges from 15% to 50% of total energy expenditure, depending on the individual; however, the majority of adults perform these activities [29]. Therefore, the energy expenditure of NEAT is much greater than that of EAT when measured throughout the day [18] [19]. These considerations led us to believe that, in this study, no correlation was found with the EAT scores but only with the NEAT scores. In other words, improving the NEAT energy content may be an important health-promoting factor not only for young adults but also for older adults.

Increasing NEAT is effective in preventing lifestyle-related diseases and has been encouraged by various guidelines [30]. However, according to Japan's National Health and Nutrition Survey, the average number of daily steps significantly decrease from 6857 (2003) to 5859 (2019) for women in their 60 s [31]. This may be due to the recent emergence of labour-saving devices such as cars and household appliances, which have reduced the need for human movement, resulting in a decrease in NEAT. In older adults, the decrease in muscle mass and activity associated with such lifestyle changes is not only associated with the progression of frailty but also with cardiovascular disease [32], type 2 diabetes mellitus [33], being overweight, and obesity [34].

The elements of NEAT activity mainly comprise activity in the antigravity posture, which is strongly related to the calf muscles. In particular, the calf muscles have a much higher density of slow-twitch fibres [35], a structure that favours endurance and may be strongly influenced by prolonged activities, such as those classified as NEAT. Harris *et al.* studied and compared the behaviour of older and younger adults with no exercise habits over a 10-day period. They found that older adults had a lower standing time, shorter walking distance, longer sitting time, and no difference in the supine position compared with younger adults [36]. Rizzato *et al.* conducted a review of NEAT consumption in young adults in different work environments and reported that simply performing sedentary tasks in a standing position increased muscle activity [37]. Even in older adults, working on environmental adjustments that make people want to walk, stand, and stand for longer durations may lead to an increase in calf circumference, muscle thickness, and prevention of frailty.

This study has some limitations. First, the participants were older women who participated in limited community activities, which means that the number of participants is small, and generalisation to other older adults is limited. It is possible that older women have different household roles depending on the number of people living together and the composition of their household and the amount of activity may vary significantly; however, this has not been investigated in this study. Therefore, in the future, it will be necessary to increase the number of participants and classify them based on their background. In addition, many older adults have a history of various diseases (metabolic syndrome, cardiac and cognitive disorders, exercise disorders, insulin resistance, and non-alcoholic fatty liver disease, among others) that may affect the calf circumference due to oedema in the lower leg. Second, participants were polarised in terms of EAT activities into those that they performed daily and those that they did not. EAT activities account for only 15% - 30% of the total energy expenditure, even among those who perform these activities regularly [25] [26]. Therefore, no correlation with the calf circumference was found; however, future comparisons between groups with low and high EAT scores could contribute to health promotion, especially in the group with low EAT scores. Finally, NEAT may contribute to an increase in maximal oxygen uptake. Satonaka *et al.* investigated the relationship between the VO_2max, an indicator of aerobic capacity, and continuous heart rate during daily physical activity in people with cerebral palsy and found that the VO_2max may be higher in adults with high daily physical activity, even without special exercise [38]. Studies comparing standing versus sitting during working hours in healthy participants have shown that not only NEAT but also heart rates are significantly increased [39]. Individuals with a higher VO_2max have lower rates of cardiovascular morbidity and mortality [40] [41]. However, whether NEAT in older adults is associated with the maintenance of aerobic capacity remains unclear. Measurement of the VO_2max in older adults requires specialised equipment, and a simple assessment of the calf circumference would be useful. Therefore, it is necessary to clarify the relationship between the VO_2max and calf circumference or skeletal muscle mass under adequate risk management.

In conclusion, this study showed that the calf circumference in older women is strongly correlated with the skeletal muscle mass and calf muscle thickness and that the calf circumference is significantly related to NEAT activity. This suggests that improving daily activities, rather than special sports, may prevent and improve age-related frailty, which is of interest for the prevention of obesity and diabetes in the working population but should also be addressed to maintain physical fitness in older women.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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