HSPI The Open Access Publisher

JCMHS JOURNAL OF COMMUNITY MEDICINE AND HEALTH SOLUTIONS

Research Article

Associations of Exercise Habits and Circulatory Dynamics with Peripheral Lower Limb Body Composition in Healthy Community-dwelling Older Individuals

Haruki Kogo[1]*, Yuh Yamashita[2] and Jun Murata[2]

[1]Faculty of Rehabilitation Science, Reiwa Health Science University, Japan
[2]Graduate School of Biomedical Sciences, Nagasaki University, Nagasaki, Japan

Abstract

We investigated the associations between circulatory dynamics and Body Composition (BC) of the peripheral lower limbs with Exercise Habits (EHs). We surveyed the EHs of 34 healthy older adults (6 men, 28 women) and measured their BC and skin perfusion (SP). SP did not correlate significantly with any other variable. Participants with established EHs had a lower body weight and Fat Tissue thickness (Fat-T) than those without. Multiple logistic regressions with the presence or absence of an EH as the dependent variable and BC values as the independent variables established Fat-T as a significant variable. Sex was independently associated with soleus muscle thickness, Fat-T, Bone Density (BD), and leg segmental water. Age was independently associated with Fat-T and BD, and body mass index was associated with Fat-T. EHs were not independently associated with any of the BC measurements. Physical characteristics and EHs have minimal influence on peripheral circulatory dynamics.

More Information

***Address for Correspondence:** Haruki Kogo, Faculty of Rehabilitation Science, Reiwa Health Science University, 2-1-12, Wajirogaoka, Higashiku, Fukuoka-shi, Fukuoka-ken 811-0213, Japan, Tel: +81-92-608-8600; Fax: +81-92-608-8601; Email: h.kogo@rhs-u.ac.jp

Submitted: February 28, 2022
Approved: April 14, 2022
Published: April 15, 2022

How to cite this article: Kogo H, Yamashita Y, Murata J. Associations of Exercise Habits and Circulatory Dynamics with Peripheral Lower Limb Body Composition in Healthy Community-dwelling Older Individuals. J Community Med Health Solut. 2022; 3: 027-034.

DOI: 10.29328/journal.jcmhs.1001017

Keywords: Skin perfusion; Physical characteristics; Muscle thickness; Fat thickness; Older adults

The concept of "active life expectancy" is defined as the period during which the Activities of Daily Living (ADL) can be performed independently [1]. In Japan, the term "healthy life expectancy" [2] is used to indicate the period during which there are no limitations in ADL. The average life expectancy in Japan has increased due to the improvements in living environments and medical advances, and women have a better healthy life expectancy than men, with a difference of approximately 10 years (Ministry of Health, Labour, and Welfare). Therefore, extending healthy life expectancy is an important issue [3]. Prevention of disease, the need for long-term care, and promotion of health are part of the Ministry of Health, Labour, and Welfare's Kenko Nippon 21's (Healthy Japan 21) initiative, which was launched in 2000 [4]. The initiative includes various policies to reduce this disparity.

Diseases that limit ADL include cardiovascular, cerebrovascular, and musculoskeletal diseases, as well as dementia. Lifestyle-related conditions, such as hypertension, diabetes, dyslipidemia, and obesity, are risk factors for the development of vascular diseases. To avoid these conditions, behavioral changes are required to improve dietary and Exercise Habits (EHs) [5]. Locomotive syndrome [6]—a condition in which a person is at high risk of needing long-term care that is caused by age or isolation—is a risk factor for musculoskeletal disorders and the development of dementia in older adults. Indeed, lifestyle diseases, locomotive syndrome, and dementia are three major causes of reduced healthy life expectancy [6].

Nationwide initiatives for extending healthy life expectancy aimed at preventing lifestyle diseases, locomotive syndrome, and dementia, have been the subject of much research in Japan. Uemura, et al. [7] conducted a 24-week educational intervention on community-dwelling older adults and found that compared with a control group, the group that received the health education intervention exhibited improvement in terms of results for an apathy scale; indicators of motor function, such as walking speed, the five times sit-to-stand test, and physical activity; a dietary diversity score; and a self-efficacy scale for health management. In addition, a study that examined the effects of specific health guidance reported improvement in obesity [which is a lifestyle disease [8], lower blood pressure due to weight loss, and improved lipid metabolism [9].

In a study that examined an intervention to prevent the locomotive syndrome, it was confirmed that classes combining nutrition and exercise could prevent the need for long-term care [10]. A fall prevention study that compared community-dwelling middle-aged and older people with and without a history of falling found that in men, the fall history group had significantly poorer motor functions (lower limb strength, toe grip, and standing balance) [11]. Further, intervention effects, such as the training of lower limb muscle strength/standing balance ability [12] and toe grip force [13], have been recognized.

Health education, specific health guidance, and lower limb exercise interventions have been found to be effective in preventing lifestyle diseases, locomotive syndrome, and dementia. Moreover, exercises to strengthen the lower limbs have been recommended [14].

Although humans have automatic physiological functions (respiration, circulation, and thermoregulation) that act to maintain life, much is still unknown about their specific mechanisms [15]. Regarding hemodynamics, which has a major impact on the development of vascular disease, it has been reported that under exercise load, Skin Perfusion (SP) is lower in older people than in young people [16,17]; however, some studies have also shown that age has no effect [18], thereby indicating a lack of consensus in this regard. Moreover, because only a few studies have investigated the relationship between circulatory dynamics and Body Composition (BC), there is little evidence regarding this topic. Therefore, obtaining basic findings regarding the circulatory dynamics of healthy older people could aid in the extension of healthy life expectancies.

In this study we aimed to study whether subjects with and without EH have differences in body characteristics or in SP of their lower limbs.

Methods

Participants

This cross-sectional study was performed on October 12, 2019, and October 30, 2019. Fifty healthy people who participated in an annual health metric event (no age restrictions for participation) held by the University in the local community were recruited using a magazine flyer. Participants over 60 years of age and who provided informed consent were included in this study. The exclusion criteria were adults undergoing outpatient therapy and those on medication, having a medical history involving limitations on ADL, having a pacemaker, being in poor health that day, and having missing values in the data collected. The participants were immediately informed of the measurement results orally and in writing.

In accordance with the Declaration of Helsinki, we provided oral and written explanations to each participant about the objectives and content of the study, that the data would not be used for anything except the study, that proper consideration would be given to the handling of their personal information, and that they could refuse to participate at any time. In addition, they were informed that participation in the study was of their own free will and accord and that there would be no disadvantage to not participating. The survey began once an informed consent form was signed. This study was conducted with the approval of the Ethical Review Board of [BLINDED FOR REVIEW].

Survey items

The survey items were the physical characteristics of participants, namely, their age, sex, height, weight, Body Mass Index (BMI), blood pressure, pulse rate, EHs, muscle thickness, fat thickness, and Bone Density (BD), body water content, and hemodynamics. For all participants, the survey was conducted in the morning before lunch in the community center that was maintained at 26ºC.

Measurement of participant physical characteristics, blood pressure and pulse rate

First, participants were asked about their physical condition, followed by an interview and measurements of blood pressure and pulse rate. The participants sat on a chair with their right arm resting on a desk at the same height as their heart. The examiner used a digital sphygmomanometer (HEM-7132, Omron) to measure blood pressure at the brachial artery and measured the pulse by palpating the radial artery. Next, participants were asked about their age and sex, and their height and weight were measured with a digital height meter (DSN-90, Muratec KDS) and scale (HS-650, Tanita).

Questionnaire on exercise habits

The questionnaire required participants to describe the "presence or absence of an EH," "types of exercises," "exercise time," "exercise frequency," "months/years exercise has continued," "exercise history," "period of exercise history," and "type of exercise history." According to Slentz, et al. [19], moderate exercise of ≥ 30 min per day can prevent weight gain. As the participants of this study were older, those who exercised for ≥30min per day, for ≥1 h total per week, and had continued this for ≥ 3 months were assessed as having an EH.

Evaluation of muscle and fat thickness

The structural evaluation of muscle and fat thickness is generally performed with imaging methods, such as computed tomography, magnetic resonance imaging, or ultrasonogram (US). Among these, the US is often used because it is simple and minimally invasive. Moreover, when evaluating the structure of muscle and fat tissues, for devices using Bioelectrical Impedance Analysis (BIA), body water content is susceptible to diet, urination, or defecation status [20]; therefore, US was used in this study. The gastrocnemius was selected as the site for evaluating muscle thickness on the peripheral lower limbs because the ankle area is abundant in tendon tissue and little muscle [14,21] and because this muscle exhibits age-related muscular atrophy i.e., sarcopenia. The measurement protocol was based on data from previous studies [22-24]. Gastrocnemius muscle thickness (GM-T) was measured at the medial head, perpendicular to the bone surface at a site 30% proximal along a line connecting the medial epicondyle of the femur with the calcaneal tuberosity. Soleus muscle thickness (SM-T) was measured as the layer directly below and Fat Thickness (Fat-T) as the layer directly above using a measuring instrument (Viamo, SSA-640A, Toshiba Medical) and linear probe (PLT-1204ST, Toshiba Medical) at a frequency of 7.5 MHz in B mode. The participant laid prone on a mat and was instructed by the examiner to place the ankle in plantar flexion so that the muscle did not contract. After gently placing the probe on the evaluation site and after the screen stabilized, the measurement's start and endpoints were marked using a marker, and the device was used to calculate the distance between these two points. The measurements were repeated three times each on the left and right soleus muscle, and the medians of the three were recorded after discarding the maximum and minimum values. The mean of the left and right measurements were then used as the representative value for statistical analysis. Because the reproducibility of tissue thickness assessments with the US varies by the assessor [23], an assessor with 6 years of US experience performed the measurements for all the participants.

Evaluation of bone density (BD)

The evaluation site was the calcaneus, and the measurements were performed using an ultrasonic bone density device (CM-200, Furuno Electric) with bone propagation velocity as the indicator. The participants were seated in a chair with their socks removed to expose the heel, so the instrument could be placed to measure propagation velocity in the calcaneus bone. Bone propagation velocity was measured once each on the left and right, and the mean was used as the representative value for statistical analysis.

Evaluation of body water content

Body water content cannot be measured on the peripheral lower limbs only, and therefore the entire lower limbs were examined. The measurements were performed using the BIA method (InBody S10, InBody), in which the InBody S10 used the 8-point contact electrode method with two electrodes attached to both the left and right ankles and a device with six wideband frequencies [25] to noninvasively quantify body water content [26]. The participants were instructed to remove any metal accessories and precious metals and to sit in a chair to measure Leg Segmental Water (L-SW). L-SW was measured once on each side, and the left and the right mean was used as the representative value for statistical analysis.

Evaluation of circulatory dynamics

Microcirculation of the skin was measured above the third metatarsal in the center of the dorsum of the foot. The measuring instrument was a laser blood flow monitor (Nahri MV monitor, Nexis). The participants laid supine on a mat and after resting for 1 min, the SP was measured for 1 min. SP was measured once each on the left and right, and the mean was used as the representative value for statistical analysis.

Statistical analysis

For statistical processing, normality was confirmed using the Shapiro-Wilk test. Univariate analysis was performed by calculating Pearson's correlation coefficients between age, height, weight, BMI, GM-T, SM-T, Fat-T, BD, L-SW, and SP.

The participants were then divided into two groups based on the presence or absence of an EH. Sex was compared between the groups using the χ^2 test; an unpaired *t*-test was used for the other variables. An EH was used as the dependent variable and BC values (GM-T, SM-T, Fat-T, BD, and L-SW) were the independent variables in multiple logistic regression analysis using the forward stepwise method.

Table 1: Physical characteristics of the participants.

Item	Overall (*n* = 34)	Men (*n* = 6)	Women (*n* = 28)
Age (years)	75.5 ± 6.6	74.2 ± 6.6	75.8 ± 6.7
Height (cm)	152.3 ± 7.1	161.5 ± 7.0	150.3 ± 5.4
Weight (kg)	54.1 ± 9.8	66.3 ± 5.5	51.5 ± 8.4
BMI (kg/m²)	23.3 ± 3.3	25.5 ± 2.6	22.8 ± 3.2

Mean ± standard deviation; BMI: Body Mass Index.

Table 2: Physical characteristics and body composition values in groups with and without exercise habits (*n* = 34).

Item	Overall (*n* = 34)	Exercise habit (*n* = 20)	No exercise habit (*n* =14)	*p* - value
Age (years)	75.5 ± 6.6	76.1 ± 7.6	74.8 ± 5.1	0.591
Sex, *n* (%), Female	28	12(85.7)	16(80.0)	0.998
Male	6	2(14.3)	4(20.0)	
Height (cm)	152.3 ± 7.1	150.4 ± 6.7	155.0 ± 6.8	0.061
Weight (kg)	54.1 ± 9.8	51.0 ± 9.1	58.6 ± 9.1	0.023*
BMI (kg/m²)	23.3 ± 3.3	22.5 ± 3.4	24.3 ± 2.8	0.117
GM-T (mm)	14.19 ± 2.07	14.10 ± 2.42	14.31 ± 1.51	0.778
SM-T (mm)	19.02 ± 2.56	19.29 ± 2.11	18.64 ± 3.14	0.474
Fat-T (mm)	5.68 ± 1.52	5.14 ± 1.11	6.45 ± 1.71	0.011*
BD (m/sec)	1466.94 ± 31.02	1466.40 ± 31.38	1467.71 ± 31.65	0.905
L-SW (L)	4.40 ± 1.11	4.22 ± 1.12	4.67 ± 1.07	0.250
SP (mL/ min/100 g)	8.65 ± 2.84	8.58 ± 3.02	8.76 ± 2.66	0.863

The χ^2 test was used for sex, and an unpaired *t* - test was used for all others*: $p < 0.05$, mean ± standard deviation or n.
BMI: Body Mass Index; GM-T: Gastrocnemius Muscle Thickness; SM-T: Soleus Muscle Thickness, Fat-T: Fat Tissue Thickness; BD: Bone Density; L-SW: Leg Segmental Water; SP: Skin Perfusion

Table 3: Relationship between physical characteristics, body composition, and dermal blood flow (*n* = 34).

	Age	Height	Weight	BMI	GM-T	SM-T	Fat-T	BD	L-SW
Height	-0.418*								
Weight	0.068	0.635**							
BMI	0.351*	0.146	0.855**						
GM-T	-0.258	0.374*	0.345*	0.208					
SM-T	-0.024	0.395*	0.246	0.025	0.287				
Fat-T	0.071	-0.151	0.319	0.524**	0.216	-0.326			
BD	-0.486**	0.566**	0.344*	0.070	0.198	0.203	-0.228		
L-SW	-0.092	0.806**	0.806**	0.491**	0.320	0.397*	-0.105	0.584**	
SP	0.243	-0.146	0.072	0.198	-0.041	-0.303	0.253	-0.010	0.045

Values are Pearson's correlation coefficients*: $p < 0.05$**: $p < 0.01$
BMI: Body Mass Index; GM-T: Gastrocnemius Muscle Thickness; SM-T: Soleus Muscle Thickness; Fat-T: Fat Tissue Thickness; BD: Bone Density; L-SW: Leg Segmental Water; SP: Skin Perfusion

Forced entry multiple regression was also performed with BC and SP as dependent variables, physical characteristics (age, sex, and BMI), and an EH as independent variables. The statistical analyses were performed with IBM SPSS Statistics (Ver 24.0) with a 5% significance level in all cases.

Results

Participants, surveys and measurements

Of the 50 people who participated in the health event, 34 (6 men, 28 women) met all the inclusion criteria. None of the participants had a pacemaker or felt unwell on the day of the survey. The characteristics (average±standard deviation) of the men were: age 74.2 ± 6.6 years, height 161.5 ± 7.0 cm, weight 66.3 ± 5.5 kg, and BMI 25.5 ± 2.6 kg/m^2; the characteristics of women were: age 75.8 ± 6.7 years, height 150.3 ± 5.4 cm, weight 51.5 ± 8.4 kg, and BMI 22.8 ± 3.2 kg/m^2 (Table 1). These physical characteristics are summarized in Table 1.

The results of the survey showed that 20 people had an EH (27 types). The type of exercise was walking in six people, jogging in one, golf or ground golf in two, qi gong in nine, gymnastics in three, dance in two, swimming (pool) in two, using a fitness gym in one, and table tennis in one. They had engaged in exercise continuously for 6 months to 20 years. The measurements for the participants overall were GM-T, 14.19 ± 2.07 mm; SM-T, 19.02 ± 2.56 mm; Fat-T, 5.68 ± 1.52 mm; BD, 1466.94 ± 31.02 m/s; Leg-SW, 4.40 ± 1.11L; and SP, 8.65 ± 2.84 mL/min/100 g (Table 2).

Univariate analysis

Table 3 shows the Pearson's correlation coefficients for all items. For lower limb BC and circulatory dynamics, GM-T correlated significantly with height (r = 0.374) and weight (r = 0.345). SM-T correlated significantly with height (r = 0.395) and L-SW (r = 0.397). Fat-T correlated significantly with BMI (r = 0.524). BD correlated significantly with age (r = -0.486), height (r = 0.566), weight (r = 0.344), and L-SW (r = 0.584). L-SW correlated significantly with height (r = 0.806), weight (r = 0.806), BMI (r = 0.491), SM-T (r = 0.397), and BD (r = 0.584). SP did not correlate significantly with any variable.

Table 4: Multiple logistic regression analysis of the presence or absence of an exercise habit.

Variable	Odds ratio	95% confidence interval	*p* - value
Fat-T	0.373	0.170–0.819	0.014

Forward stepwise method (likelihood ratio). Fat-T: Fat-Thickness.

Table 5: Multiple regression results (*n* = 34).

Dependent variable	Extracted factor	Standardized coefficient β	*p* - value
SM-T	Sex	0.564	0.003
Fat-T	Sex	-0.688	0.000
	Age	-0.265	0.020
	BMI	0.804	0.000
BD	Sex	0.481	0.003
	Age	-0.469	0.004
L-SW	Sex	0.611	0.000
SP	no factor		

Multiple regression analysis using the forced entry method was used with body composition as the dependent variable and physical characteristics (age, sex, and BMI) and exercise habit as the independent variables.
BMI: Body Mass Index; GM-T: Gastrocnemius Muscle Thickness; SM-T: Soleus Muscle Thickness; Fat-T: Fat Tissue Thickness; BD: Bone Density; L-SW: Leg Segmental Water; SP: Skin Perfusion

Comparison of variables based on exercise habits

Table 2 shows the comparisons of physical characteristics and items based on the presence or absence of an EH. Compared with the group with no EH, the group with EHs had significantly lower body weight (p = 0.023) and Fat-T (p = 0.011), although the other variables were not significantly different.

Multiple logistic regression analysis

On multiple logistic regression analysis, using the presence or absence of EH as the dependent variable and BC values as the independent variables, Fat-T was identified as a significant predictive variable (odds ratio: 0.373, 95% confidence interval: 0.170–0.819) as a significant variable (Table 4). The predictive value of the assessments was 73.5%, specificity was 85.0%, sensitivity was 57.1%, and Nagelkerke's R^2 was

0.448. The logistic regression model was: 33.092 + (-0.177 × height) + (-0.987 × Fat-T).

Multiple regression analysis

Table 4 shows the results of the multiple regression analysis with BC and SP as dependent variables and physical characteristics and EH as independent variables. Sex was extracted as being independently associated with SM-T, Fat-T, BD, and L-SW. Age was independently associated with Fat-T and BD, and BMI was associated with Fat-T. However, EH was not found to be independently associated with any of the BC values (Table 5). Moreover, no factor was independently associated with SP.

Discussion

We examined how BC and circulatory dynamics in the peripheral lower limbs relate to EHs in healthy community-dwelling older people. The results showed weak positive correlations between muscle thickness (GM-T and SM-T) and the physical characteristics of height and weight.

In their study, Abe, et al. [27] reported an association between age and muscle volume of the lower limbs and trunk among Japanese men and women aged 20 to 95 years. Age was strongly and inversely correlated with quadriceps volume/length and abdominal muscle volume/height in both men and women, with only a weak correlation between age and muscle volume at other measurement sites of the lower limbs and trunk. Although the participants of this study differed somewhat, our results mostly confirm previous findings, suggesting that muscle thickness in the peripheral lower limbs in healthy older people is associated with height and weight (predominantly height), but not with age. We selected the medial head of the gastrocnemius to assess, as this muscle is particularly susceptible to sarcopenia. However, the results may have been affected by the fact that we only included highly health-conscious older people who voluntarily participated in a health event. Due to the likely presence of other confounding factors, such as lifestyle habits (e.g., diet, exercise), we cannot say for certain whether muscle thickness is associated with age.

Fat-T exhibited a moderate positive correlation with BMI. Both BMI and the body fat ratio are used as indicators of obesity [28]. The body fat ratio has been found to correlate strongly with BMI although the correlation coefficient between Fat-T and BMI in this study (r = 0.524) was lower than that previously reported. The body fat ratio is the proportion of fat in all body tissues. We believe this is why the correlation with Fat-T in the lower limbs was weaker in this study than in previous studies.

BD exhibited a moderate negative association with age, a moderate positive association with height, a weak positive association with weight, and a moderate positive association with L-SW. Yokouchi, et al. [29] conducted a longitudinal investigation of changes in bone mass in female university students. They found that bone mass changes were affected by the physique and had a particularly strong association with lean mass. The results of this study largely confirm the findings of previous research. Previous studies regarding the relationship between body weight, BC, and BD in older people have shown that both lean mass and fat mass correlate with BD [30] and that BD corrected for height correlates positively with body weight [31]. This indicates that the mechanical force of body weight has a protective effect on the skeleton. Indeed, because nutritional status has also been reported to be associated with BD in older adults [32], it is possible that nutritional status and the mechanical force of body weight indirectly affect the relationship between BD and weight, although this study was unable to confirm this kind of causal relationship.

L-SW exhibited a strong positive association with height and weight, a moderate positive association with BMI, a weak positive association with SM-T, and a moderate association with BD. Muraoka and Komiya [33] evaluated body water content with an estimation formula using the BIA method in healthy men and women aged 18 to 74 years. Their analysis showed that body water content had a strong correlation with weight and height. The association between L-SW and physique observed in this study confirms the results of previous research, and again, demonstrates that the amount of water in the body increases or decreases along with physique.

Interestingly, none of the items correlated significantly with SP. In humans, SP increases and decreases alongside changes in environmental and core temperature [34]. In hot environments and at high body temperatures, blood vessels in the skin dilate so that large amounts of blood can flow near the body surface to promote heat dissipation. Conversely, in cold environments and at low body temperatures, blood vessels in the skin contract to prevent heat dissipation [34]. Adaptability to the thermal environment is called thermoregulation, which is thought to differ based on individual characteristics [35]. These individual characteristics include characteristics, such as physique and age, as well as factors like lifestyle, EHs, acclimation to hot environments, aerobic exercise capacity, and hydration status, which create differences in the ability of individuals to adapt to heat [35]. Therefore, it is possible that the influence of these individual characteristics was a major reason why no items were found to be associated with peripheral circulation in the lower limbs.

Physique also affects the body surface area. A larger body surface area is advantageous for heat dissipation, while obesity is seen as advantageous for heat storage [36]. However, a significant association between SP and physique was not observed in this study. This may be because of the small sample size and variation in the participants' physiques. Further, the participants of this study were health-conscious older people who voluntarily responded to an invitation to a health event. Forearm SP was not significantly associated with the amount of sweat in people in their 60s or in young people with EHs [37], which indicates an individual's EHs and aerobic exercise ability have a major effect on SP. Regarding the effects of environmental temperature, because the temperature of the room used in this study was maintained at 26 ºC, there was little need for thermoregulatory functions. This would also maintain the participants' blood flow rate, which could be why no items were significantly associated with SP.

In the comparisons of groups with and without EHs, body weight and Fat-T were significantly smaller in the EH group. In the multiple logistic regression analysis, Fat-T was selected as a significant variable associated with the presence or absence of an EH. In the multiple regression analysis, sex was an independent factor associated with SM-T, Fat-T, BD, and L-SW; age was independently associated with Fat-T and BD, and BMI was independently associated with Fat-T. However, an EH was not extracted as independently associated with any of the BC values. Additionally, no factors were independently associated with SP. It is generally believed that arterial walls harden with age, although more than the effects of age, changes in carotid atherosclerosis are thought to be accelerated by risk factors, such as coexisting cardiovascular disease and obesity [38]. Di Iorio, et al. [39] divided 52 middle-aged and older participants into three groups based on fat and muscle mass. They found that the cardio-ankle vascular index, a novel indicator of arteriosclerosis, was significantly higher in the upper 1/3 group of fat mass and lower 1/3 group of muscle mass. Arteriosclerosis increases systolic blood pressure and is involved in the development of hypertension [40], while diastolic blood pressure is thought to arise when people are in their 50s and 60s and drop thereafter [41]. These circulatory dynamics reduce the amount of blood stored during the systolic stage, which may reduce blood flow to the periphery during the diastolic stage [42]. In addition, while low-load strength training improved peripheral circulation in healthy older people [43], Proctor, et al. [44] reported that in healthy older and younger individuals with EHs, blood flow in the lower limbs was significantly lower during exercise in older people than in younger people. As the participants of this study were older, they had decreased blood flow to the periphery, which may be why the presence or absence of an EH had little influence on SP. These results show that in community-dwelling older people, BC was not independently associated with EHs, but rather was greatly affected by physical characteristics. Moreover, physical characteristics and EHs had little impact on resting peripheral SP, which suggests this may not very much [45].

As we did not evaluate dietary habits or physiological functions, such as aerobic exercise ability, heat adaptation, and sweating ability, these factors could be a source of bias. Thus, a task for future studies is to incorporate assessments of physiological functions and dietary habits. In addition, the amount of exercise used as a basis to define EH in this study was to simply facilitate the division of the participants into those with and without EH and is not expected to improve obesity, decrease blood pressure due to weight loss, and improve lipid metabolism. Therefore, the results of multiple logistic regression analysis have limited scope. Other limitations of this study include the small sample size and the that the participants were highly health-conscious older people who voluntarily participated in a health metric event. More certain results could be derived by increasing the number of participants. Moreover, the use of some physiological tests (temperature, occlusive, orthostatic) would further improve such studies.

Conclusion

In this study of community-dwelling older people, muscle thickness was positively correlated with height and weight, although no association with age was observed. Fat thickness was positively correlated with BMI, and BD was positively correlated with age, height, weight, and body water content. Body water content was also positively correlated with height, weight, BMI, muscle thickness, and BD. However, no items were associated with SP. Further, body weight and Fat-T were significantly smaller in the group with EHs than in the group without, and Fat-T was selected as a significant variable associated with the presence or absence of an EH. Sex was independently associated with SM-T, Fat-T, BD, and L-SW; age was independently associated with Fat-T and BD, and BMI was independently associated with Fat-T. However, an EH was not independently associated with any of the BC values. In addition, no factors were independently associated with SP.

These results suggest that BC values increase or decrease along with the physique and that while fat thickness has a strong influence on EH motivation an EH has minimum impact on fat thickness, which suggests that physical characteristics and EHs have minimal influence on peripheral circulatory dynamics.

Acknowledgement

We would like to express our deep gratitude to all the participants and to the staff who conducted the survey and measurements for their cooperation in carrying out this study. We would like to thank Editage (www.editage.jp) for English language editing. This study was funded in part by a Grant-in-Aid for Scientific Research (19K20169) from the Japan Society for the Promotion of Science.

References

1. Miyabara H, Takeshita J. The relation of exercise performance with healthy life span in the community dwelling elderly—a 3 year follow-up study. J Japanese Phys Ther Soc 2004; 31: 155-159.
2. Ministry of Health, Labour, and Welfare. Examining mean life expectancy and healthy life expectancy 2020.
3. Okazaki K. The way to extend our healthy life span. J Japanese Physiol Anthropol Soc. 2017; 22: 39-44.

4. Takei M. Health promotion through exercise: - Easy to walk, I'm fine today. Japanese J Juntendo Egaku. 2002; 48: 330-334.
5. Tsushita I. Prospects for health and medical strategies from fiscal 2018 onward based on the effects and challenges of specific health checks and specific health guidance. J Japan Soc Ningen Dock. 2016; 31: 7-21.
6. Saito S. What is locomotive syndrome? Nichidai Igaku Zasshi. 2015; 74: 122-127.
7. Uemura K, Yamada M, Okamoto H. Effects of health education intervention through active learning for preventing frailty in older adults. Phys Ther Japan. 2018; 45: 209-217.
8. Yoshida N, Nakamura K, Kawai H, Hoshino K, Kume S. Comparison of 2nd fiscal year's medical checkup results between examinees who received specific health guidance for metabolic syndrome and those who received no guidance. J Japan Soc Ningen Dock. 2012; 27: 707-714.
9. Imawatari R, Ogawa M, Hamao Y, Kitahara N, Uno T, et al. Study on changes in various indicators due to specific health guidance. J Japan Soc Ningen Dock. 2011; 26: 44-50.
10. Fukasaku T, Okuno J, Tomura S, Seino S, Kim MJ, et al. Intervention effects of inclusive support in an "exercise and a nutritional community-based prevention program" for pre-frail elderly individuals. Nihon Koshu Eisei Zasshi. 2011; 58: 420-432. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/21970076/
11. Yumura R, Ishibashi H, Fujita H. Association of fall history with locomotive syndrome severity test and motor function measurements in community-dwelling middle-aged and elderly people. Rigaku-Ryouhou Rinnsyou Kenkyuu Kyouiku. 2016; 23: 40-46.
12 Arai T, Obuchi S, Kojima M, Matumoto Y, Inaba Y. The evaluation of the relationships between physical factors and effects of exercise intervention on physical functions in community-dwelling older people. Nihon Ronen Igakkai Zasshi. 2006; 43: 781-788. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/17233465/
13. Arai T, Fujita H, Hosoi T, Morita Y, Ishibashi H. Toe flexor muscle strength as a measure of motor function in community-dwelling elderly people. J Japanese Phy Ther Soc. 2011; 38: 489-496.
14. Perkisas S, Baudry S, Bauer J, Beckwée D, De Cock A, et al. Application of ultrasound for muscle assessment in sarcopenia: towards standardized measurements. Eur Geriatr Med. 9: 739-757. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/34674473/
15. Waki H. Symposium 1-11: Central breathing, circulation, and thermoregulation mechanisms during exercises—Understanding the black box. Japanese J Phys Fit Sports Med. 2013; 62: 17-61.
16. Kenney WL. Control of heat-induced cutaneous vasodilatation in relation to age. Eur J Appl Physiol Occup Physiol. 1988; 57: 120-125. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/3342787/
17. Kenney WL, Havenith G. Heat stress and age: skin blood flow and body temperature. J Therm Biol. 1993; 18: 341-344.
18. Drinkwater BL, Bedi JF, Loucks AB, Roche S, Horvath SM. Sweating sensitivity and capacity of women in relation to age. J Appl Physiol Respir Environ Exerc Physiol. 1982; 53: 671-676. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/7129989/
19. Slentz CA, Duscha BD, Johnson JL, Ketchum K, Aiken LB, et al. Effects of the amount of exercise on body weight, body composition, and measures of central obesity: STRRIDE--a randomized controlled study. Arch Intern Med. 2004; 164: 31-39. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/14718319/
20. Imai Y, Kubo A. Relationships between body composition and nutrition in young females. Rigakuryoho Kagaku. 2019; 34: 713-717.
21. Abe T, Kumagai K, Brechue WF. Fascicle length of leg muscles is greater in sprinters than distance runners. Med Sci Sports Exerc. 2000; 32: 1125-1129. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/10862540/
22. Akagi R, Chino K, Dohi M, Takahashi H. Relationships between muscle size and hardness of the medial gastrocnemius at different ankle joint angles in young men. Acta Radiologica. 2012; 53: 307-311. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/22302209/
23. Fukumoto Y, Ikezoe T, Yamada Y, Ichihashi N. Assessment of muscle quantity and quality with ultrasonography. Phys Ther Japan.2015; 42: 65-71.
24. Kogo H, Yamashita Y. Characteristics of the rotator cuff muscle thickness in baseball players using ultrasound images. Japanese J Health Promot Phys Ther. 2020; 9: 187-193.
25. Kubo A, Tanaka S, Ookawa H, Murata S. Locomotive syndrome among middle-aged females, the characteristics of their body composition and their physical ability. Japanese J Health Promot Phys Ther. 2019; 9: 19-23.
26. Sasaki N, Ueno K, Shiraishi T, Kuno M, Nakazawa E, et al. Assessment of body fluid component in hemodialyzed patients using a body composition analyzer (InBody S20): can the bioelectrical impedance method be a marker of dry weight? Nihon Toseki Igakkai Zasshi. 2007; 40: 581-588.
27. Abe T, Sakamoto M, Yasuda T, Bemben MG, Kondo M, et al. Age-related, site-specific muscle loss in 1507 Japanese men and women aged 20 to 95 years. J Sports Sci Med. 2011; 10: 145-150. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/24149307/
28. Arai T. Correlations among obesity index, body mass index, percent body fat and other clinical signs. Evaluations of obesity as the risk factor for various diseases. Kenkou igaku, Japanese J Health Med. 1999; 14: 168-173.
29. Yokouchi J, Ando D, Ono Y, Ozaki Y, Asakawa K, et al. Influence of anthropometric measures and lifestyle-related factors on the two-year changes of bone mass in college-aged women. Japanese J Phys Fit Sports Med. 2006; 55: 331-340.
30. Khosla S, Atkinson EJ, Riggs BL, Melton LJ. Relationship between body composition and bone mass in women. J Bone Miner Res. 1996; 11: 857-863. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/8725184/
31. Harris SS, Dawson-Hughes B. Weight, body composition, and bone density in postmenopausal women. Calcif Tissue Int. 1996; 59: 428-432. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/8939766/
32. Sakai R, Yamada S, Nima Y, Hamasaki T, Dewake N, et al. Relation between nutritional-health status and the current-past medical history in elderly outpatients. Part 1. J Japan Diete Assoc. 2014; 57: 28-37.
33. Muraoka Y, Komiya S. Equation for estimating total body water by bioelectrical impedance measurements in Japanese subjects. The Ann Physiol Anthropol. 1991; 10: 203-210. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/1810307/
34. Ozawa T, Fukuda K. (supervising editor). Hyojun seirigaku. Tokyo: Igaku-Shoin Ltd. 2014; 874-876.
35. Maeda S, Date Y, Nishimura T, Niimura M, Hayashi M, et al. Relationship between core temperature and physiological measurement during incremental load test under hot environment-basic research for preventing heat stroke. J Japanese Physiol Anthropol Soc. 2018; 23: 155-163.
36. Ueno S. Relationship between aging and thermoregulation. Japanese J Occupatio Med Traumatol. 2016; 64: 308-318.
37. Tankersley CG, Smolander J, Kenney WL, Fortney SM. Sweating and skin blood flow during exercise: effects of age and maximal oxygen uptake. J Appl Physiol. 1991; 71: 236-242. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/1917747/
38. Lee HY, Oh BH. Aging and arterial stiffness. Circ J. 2010; 74: 2257-2262. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/20962429/
39. Di Iorio A, Di Blasio A, Napolitano G, Ripari P, Paganelli R, et al. High fat mass, low muscle mass, and arterial stiffness in a population of free-living healthy subjects: the "al passo con la

tua salute" project. Medicine. 2019; 98: e16172.
PubMed: https://pubmed.ncbi.nlm.nih.gov/31261548/

40. Ajisaka R. Health maintenance and exercise training in the elderly. Nihon Ronen Igakkai Zasshi. 43: 585-587.
PubMed: https://pubmed.ncbi.nlm.nih.gov/17073282/

41. Franklin SS, Gustin W, Wong ND, Larson MG, Weber MA, et al. Hemodynamic patterns of age-related changes in blood pressure. The Framingham Heart Study. Circulation. 1997; 96: 308-315.
PubMed: https://pubmed.ncbi.nlm.nih.gov/9236450/

42. Matsuda M. Exercise and prevention of arteriosclerosis in elderly people: effects of exercise on aging changes in central arterial distensibility. Japanese J Phys Fit Sports Med. 2003; 52: 31-37.

43. Shimizu R, Hotta K, Yamamoto S, Matsumoto T, Kamiya K, et al. Low-intensity resistance training with blood flow restriction improves vascular endothelial function and peripheral blood circulation in healthy elderly people. Eur J Appl Physiol. 2016; 116: 749-757.
PubMed: https://pubmed.ncbi.nlm.nih.gov/26822582/

44. Proctor DN, Shen PH, Dietz NM, Eickhoff TJ, Lawler LA, et al. Reduced leg blood flow during dynamic exercise in older endurance-trained men. J Appl Physiol. 1998; 85: 68-75.
PubMed: https://pubmed.ncbi.nlm.nih.gov/9655757/

45. Adams TD, Heath EM, LaMonte MJ, Gress RE, Pendleton R, et al. The relationship between body mass index and per cent body fat in the severely obese. Diabetes Obes Metab 2007; 9: 498-505.
PubMed: https://pubmed.ncbi.nlm.nih.gov/17587392/