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ORIGINAL RESEARCH ARTICLE

Relationship between skeletal muscle mass and cardiac function during exercise in community-dwelling older adults

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Abstract

Aims This study aimed to investigate the relationship between skeletal muscle mass and cardiac functional parameters in older adults during cardiopulmonary exercise testing (CPET).

Methods and results Sixty-three Japanese community-dwelling older adults were enrolled (20 men and 43 women; mean age 80 years, range 65–97 years). Cardiac functional parameters during exercise were assessed using CPET. Skeletal muscle mass index (SMI) was calculated by dividing the appendicular lean mass (measured using dual-energy X-ray absorptiometry) by height in metres squared. Subjects were divided into two groups: men with SMI $\geq$ 7.0 kg/m^2 and women with SMI $\geq$ 5.4 kg/m^2 (non-sarcopenic group); or men with SMI $<$ 7.0 kg/m^2 and women with SMI $<$ 5.4 kg/m^2 (sarcopenic group). There were significant positive correlations between SMI and peak oxygen uptake (VO_2) (r = 0.631, $P < 0.001$), and between SMI and peak VO_2/heart rate (HR) (r = 0.683, $P < 0.001$). However, only peak VO_2/HR significantly differed between groups in both sexes. Multiple linear regression analyses with peak VO_2/HR as a dependent variable showed that SMI was the only independent determinant after adjusting for potential confounders. After 4 month follow-up of 47 participants, there was still a significant positive correlation between SMI and peak VO_2/HR (r = 0.567, $P < 0.001$), and between percent change of SMI and percent change of peak VO_2/HR (r = 0.305, $P < 0.05$).

Conclusions Peak VO_2/HR, an index of stroke volume at peak exercise, was associated with SMI. This indicates that skeletal muscle mass might affect cardiac function during exercise.

Keywords Community-dwelling older adults; Skeletal muscle mass index; Cardiopulmonary exercise testing; Peak oxygen pulse; Sarcopenia

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Introduction

Sarcopenia, that is, age-associated loss of muscle mass and strength, is highly prevalent in many ageing societies.[1] It has received much clinical and research attention in recent years because of its association with significant morbidity and mortality. Indeed, sarcopenia has recently been shown to be strongly associated with increased mortality because of cardiovascular disease in community-dwelling older adults,[2] and with an unfavourable prognosis in patients with chronic

heart failure (HF).[3] Just like sarcopenia, chronic HF is highly prevalent and a major cause of death in ageing populations.[4] Previous reports have suggested a relationship between skeletal muscle mass and HF, particularly among patients with HF with preserved ejection fraction (HFpEF).[5] However, the clinical interrelationship between skeletal muscle mass and cardiac function remains to be insufficiently defined. This is particularly true in association with exercise. Therefore, it is of an importance in super-ageing societies to better define the relationship between reduction in muscle mass and strength associated with sarcopenia and changes in cardiac function that are prevalent in patients with chronic HF. The aim of this study was to investigate the relationship between skeletal muscle mass and parameters of cardiac function in community-dwelling older subjects.

Methods

Participants

Sixty-three consecutive community-dwelling older adults (20 men and 43 women) living in the Tokyo metropolitan area participated in this study. The mean age of subjects was 80 years (range 65–97 years). None of the subjects were currently hospitalized, but all were being treated on an outpatient basis at the Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology.

Exclusion criteria were as follows: unable to walk independently and required nursing care, impaired vision, impaired hearing, musculoskeletal impairments that might interfere with the ability to perform the symptom-limited exercise test, a clinically unstable condition, significant cognitive disorders and less than 64 years old. Potential participants that performed habitual exercise training were also excluded from the study. The clinical characteristics of the subjects are summarized in *Table 1A*. A follow-up assessment was conducted with 47 participants 4 months after the baseline evaluation by using the methods and procedures similar to those used at the baseline.

Skeletal muscle mass index and body mass index

Appendicular skeletal muscle mass (ASM) was measured using total body dual-energy X-ray absorptiometry (DEXA, Lunar iDXA, GE Healthcare, Tokyo, Japan). Participants were positioned for whole-body scans in accordance with the

Table 1A Clinical characteristics of the 63 chronically ill participants

Participant characteristics		
	Male [*n*(%)]	20(32%)
	Age [years; mean(range)]	79(65–97)
		Male: 82(68–97)
		Female: 79(65–93)
Physiological Assessment	Body mass index, kg/m^2	22.2±3.5
		Male: 21.8±3.5
		Female: 22.4±3.5
	Brachial-ankle pulse wave velocity, cm/min	1881±445
	Skeletal muscle mass index, kg/m^2	5.98±0.9
		Male: 6.3±1.1
		Female: 5.8±0.7
Cardiopulmonary exercise test	Peak VO_2, mL/min	811±301
	Peak VO_2/weight, mL/min/weight	15.5±4.6
	Peak VO_2/heart rate, mL/beat	6.9±2.3
	Peak heart rate, bpm	117±22
	Peak watt	63±25
	Anaerobic threshold VO_2, mL/min	581±173
	Anaerobic threshold VO_2/weight, mL/min/weight	11.1±2.8
	Anaerobic threshold VO_2 /heart rate, mL/beat	5.9±1.7
	Anaerobic threshold heart rate, bpm	99±13
	Anaerobic threshold watt	38.1±14
	⊿VO_2/⊿LOAD, mL/watt	8.0±2.0
	VE vs. VCO_2 slope	35.7±11.1
Type of illness [*n*(%)]	Hypertension	36(57%)
	Dyslipidemia	28(44%)
	Diabetes mellitus	19(30%)
	Coronary artery disease	17(27%)
	Chronic heart failure	9(14%)
	Atrial fibrillation	8(13%)
Drug [*n*(%)]	Calcium channel blocker	25(39%)
	Beta-blocker	20(30%)
	Angiotensin-converting enzyme inhibitor	14(22%)

V_E vs. VCO_2 slope, minute ventilation vs. carbon dioxide output slope; VO_2, oxygen uptake.

Table 1B Univariate correlations between a skeletal muscle mass index and age, body mass index, and the results of cardiopulmonary exercise testing

Related factors	Correlation coefficient	*P* value
Age	−0.127	n.s.
Body mass index	0.770	$P < 0.001$
Brachial-ankle pulse wave velocity	−0.278	$P < 0.05$
Peak VO_2	0.631	$P < 0.001$
Peak VO_2/weight	0.274	$P < 0.05$
Peak VO_2/heart rate	0.683	$P < 0.001$
Peak heart rate	−0.079	n.s.
Peak watts	0.540	$P < 0.001$
Anaerobic threshold VO_2	0.584	$P < 0.001$
Anaerobic threshold VO_2/weight	0.150	n.s.
Anaerobic threshold VO_2/heart rate	0.626	$P < 0.001$
Anaerobic threshold heart rate	−0.017	n.s.
Anaerobic threshold watts	0.386	$P < 0.01$
$\Delta VO_2/\Delta$work load	0.297	$P < 0.05$
VE vs. VCO_2 slope	−0.166	n.s.

n.s., not significant; peak VO_2/HR, peak oxygen uptake/heart rate; V_E vs. VCO_2 slope, minute ventilation vs. carbon dioxide output slope; VO_2, oxygen uptake.
P values were calculated using Student's *t*-test.

manufacturer's protocol. Participants lay in a supine position on the DEXA table with limbs close to the body. The whole-body lean soft tissue mass was divided into several regions, that is, arms, legs, and the trunk. The sum of the muscle mass (lean soft tissue) of the four limbs was considered as ASM, and the skeletal muscle mass index (SMI) was calculated as ASM divided by the height in metres squared (kg/m^2). Subjects were then divided into two groups based on their SMI: men with an SMI $\geq$ 7.0 kg/m^2 and women with an SMI $\geq$ 5.4 kg/m^2 (non-sarcopenic group), or men with an SMI $<$ 7.0 kg/m^2 and women with an SMI $<$ 5.4 kg/m^2 (sarcopenic group). The threshold levels for group assignment were based on the criteria of the Asian Working Group for sarcopenia.[6] Body mass index (BMI) was calculated as bodyweight/height^2 (kg/m^2).

Brachial-ankle pulse wave velocity measurement

Participants were observed under quiet resting conditions in the supine position. The brachial-ankle pulse wave velocity (baPWV) and blood pressure were measured with a vascular testing device (form PWV/ABI device; BP-203PREIII, Omron Colin, Kyoto, Japan), according to the method previously described.[7] Bilateral brachial and ankle arterial pressure waveforms were stored for 10 s by the extremity cuffs connected to a plethysmographic sensor and an oscillometric pressure sensor wrapped around the participant's arms and ankles. The baPWV was calculated from the distance between the two arterial recording sites divided by the transit time.[8] The reproducibility of baPWV was shown in a previous study.[9] The mean of the right and left baPWV values were used for analysis.

Cardiopulmonary exercise testing

All patients underwent symptom-limited bicycle ergometer cardiopulmonary exercise testing (CPET) using an upright, electromagnetically braked, cycle ergometer (Aerobike Strength Ergo-8, Mitsubishi Electronic, Tokyo, Japan), a metabolic analyser (Aeromonitor AE-310S, Minato Medical Science, Osaka, Japan), and an electrocardiogram and heart rate (HR) (Stress test system ML-9000, Fukuda denshi, Tokyo, Japan). The exercise test began with a 3 min rest on the ergometer followed by a 4 min warm-up at 0 W at 60 rpm. The load was then increased incrementally by 15 W/min during the exercise test. All CPET parameters were measured from the beginning of the initial resting period on the cycle ergometer until the end of the exercise session.

The CPET was terminated upon the patient's request or if abnormal physiologic responses occurred.[10] The CPET was also ceased if a patient was unable to continue to perform the pedalling exercise correctly. Oxygen uptake (VO_2), carbon dioxide output (VCO_2), minute ventilation (V_E), tidal volume, and frequency of respiration were smoothed with an 8-breath moving average. Peak VO_2 was defined as the highest value of VO_2 obtained during the last minute of the CPET. Peak watt was defined as the power at measured peak VO_2 with CPET. VO_2/HR, known as oxygen pulse, was calculated by dividing the moving averaged VO_2 by the HR. When respiratory exchange ratio (VCO_2/VO_2, RER) was less than 1.0 at peak exercise, the test was considered insufficient because of the participant's poor effort and the data at peak exercise were not used in the statistics. The anaerobic threshold was determined synthetically by gas exchange criteria at the point of non-linear increase in the ventilatory equivalent for oxygen and the V-slope analysis (VCO_2–VO_2 plot). The slope of the V_E–VCO_2 relationship was calculated by linear regression analysis using the values from the beginning of ramp exercise to the respiratory compensation point during the CPET and was used as an index of the ventilatory efficiency.

Statistical analysis

Pearson's correlation analyses were performed to evaluate the relationship between SMI and age, BMI, and cardiac function parameters during exercise, including peak VO_2, peak VO_2/HR, peak watts, $\Delta VO_2/\Delta$work load, and the VE vs. VCO_2 slope. Comparisons of the clinical characteristics of patients in the non-sarcopenic and sarcopenic groups, including BMI, and cardiac functional parameters during exercise, were performed using unpaired Student's *t*-test. In

addition, to examine the independent associations between peak VO_2/HR and SMI, we applied serial multiple linear regression models with peak VO_2/HR as dependent variable. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 22.0, IBM Japan, Tokyo, Japan) and a two-tailed significance level was set at $P < 0.05$ for all tests.

Ethical considerations

This study was approved by the Ethics Committee of the Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology (Authorization Number: 240301) and conforms with the principles outlined in the Declaration of Helsinki. All participants gave their written informed consent prior to data collection.

Results

We enrolled 63 patients, 68% were women, and their mean age was 80 years. Patients' baseline demographics and medication are shown in *Table 1A*. A total of 24 (38%) subjects fulfilled the criteria of the sarcopenic group and 39 (62%) those of the non-sarcopenic group. The sarcopenic group had a significantly lower mean peak VO_2 (mL/min) (692 ± 241 vs. 884 ± 313, $P < 0.05$) and peak VO_2/HR (mL/beat) (6.1 ± 1.8 vs. 7.4 ± 2.4, $P < 0.05$) than the non-sarcopenic group (*Table 2*). Of the 20 male subjects, 13 (65%) were in the sarcopenic group and 7 (35%) were in the non-sarcopenic group. Male patients in the sarcopenic group had significantly lower mean values for peak VO_2 (mL/min) (683 ± 254 vs.

Table 2 Comparison of clinical characteristics between the non-sarcopenic and sarcopenic groups

		All			Male			Female		
		Non-sarcopenic group ($n = 39$)	Sarcopenic group ($n = 24$)	*P* value	Non-sarcopenic group ($n = 7$)	Sarcopenic group ($n = 13$)	*P* value	Non-sarcopenic group ($n = 32$)	Sarcopenic group ($n = 11$)	*P* value
Age, years		80±7	80±7	n.s.	82±7	81±8	n.s.	79±7	78±7	n.s.
Body mass index, kg/m^2		23.8±3.0	19.7±2.5	<0.001	25.0±2.7	20.2±2.6	<0.01	23.6±3.1	19.0±2.4	<0.001
Brachial-ankle pulse wave velocity, cm/min		1846±437	1938±461	n.s.	1673±669	1939±331	n.s.	1884±372	1937±597	n.s.
Peak VO_2, mL/min		884±313	692±241	<0.05	1140±350	683±254	<0.01	828±280	704±236	n.s.
Peak VO_2/weight, mL/min/weight		16.1±4.6	14.4±4.5	n.s.	17.8±5.3	12.8±4.3	<0.05	15.8±4.4	16.2±4.2	n.s.
Peak VO_2/heart rate, mL/beat		7.4±2.4	6.1±1.8	<0.05	10.2±3.4	6.5±2.0	<0.01	6.8±1.6	5.6±1.6	<0.05
Peak heart rate, bpm		119±21	114±23	n.s.	114±23	104±22	n.s.	120±21	124±19	n.s.
Peak watts		68±26	53±21	<0.05	87±26	51±21	<0.01	64±25	56±20	n.s.
Anaerobic threshold VO_2, mL/min		619±179	514±141	<0.05	700±114	513±125	<0.01	599±187	514±163	n.s.
Anaerobic threshold VO_2/weight, mL/min/weight		11.3±2.8	10.6±2.9	n.s.	11.5±2.7	9.4±2.7	n.s.	11.3±2.9	11.8±2.6	n.s.
Anaerobic threshold VO_2/heart rate, mL/beat		6.2±1.7	5.2±1.5	<0.05	7.8±1.8	5.4±1.5	<0.01	5.9±1.5	5.1±1.7	n.s.
Anaerobic threshold heart rate, bpm		100±13	100±14	n.s.	92±16	98±16	n.s.	102±12	102±11	n.s.
Anaerobic threshold watt		39.7±14	35±12	n.s.	46.4±15	33.1±14	n.s.	38.1±14	37.2±10	n.s.
$\Delta VO_2/\Delta$work load, mL/watt		8.1±2.2	8.0±1.7	n.s.	9.7±1.3	7.5±1.7	<0.01	7.7±2.2	8.5±1.7	n.s.
VE vs. VCO_2 slope		35.7±10.4	35.8±12.6	n.s.	34.8±6.4	37.6±11.2	n.s.	35.9±11.1	34.0±14.1	n.s.
Hypertension	(+)	26	10	n.s.	5	6	n.s.	21	4	n.s.
	(−)	13	14		2	7		11	7	
Dyslipidemia	(+)	21	7	n.s.	3	4	n.s.	18	3	n.s.
	(−)	18	17		4	9		14	8	
Diabetes mellitus	(+)	11	8	n.s.	1	5	n.s.	10	3	n.s.
	(−)	28	16		6	8		22	8	
Coronary artery disease	(+)	9	8	n.s.	3	6	n.s.	6	2	n.s.
	(−)	30	16		4	7		26	9	
Chronic heart failure	(+)	4	5	n.s.	1	4	n.s.	3	1	n.s.
	(−)	35	19		6	9		29	10	
Atrial fibrillation	(+)	6	2	n.s.	0	2	n.s.	6	0	n.s.
	(−)	33	22		7	11		26	11	
Beta-blocker treatment	(+)	11	9	n.s.	2	7	n.s.	9	2	n.s.
	(−)	28	15		5	6		23	9	

n.s., not significant; peak VO_2/HR, peak oxygen uptake/heart rate; V_E vs. VCO_2 slope, minute ventilation vs. carbon dioxide output slope; VO_2, oxygen uptake.
Numerical data are expressed as mean ± SD.
P values were calculated using Student's *t*-test.
Participants were classified as being in the non-sarcopenic group and sarcopenic group based on the Asian sarcopenia cut-off values for muscle mass measurements (7.0 kg/m^2 for men and 5.4 kg/m^2 for women as measured by dual X-ray absorptiometry).[6]

1140 ± 350, $P < 0.01$), peak VO_2/HR (mL/beat) (6.5 ± 2.0 vs. 10.2 ± 3.4, $P < 0.01$), peak watts (W) (51 ± 21 vs. 87 ± 26, $P < 0.01$), and $\Delta VO_2/\Delta$work load (mL/W) (7.5 ± 1.7 vs. 9.7 ± 1.3, $P < 0.01$) than male patients in the non-sarcopenic group (*Table 2*). In contrast, 11 (26%) of the 43 female subjects were in the sarcopenic group and 32 (74%) were in the non-sarcopenic group. Female patients in the sarcopenic group had lower peak VO_2/HR (mL/beat) values (5.6 ± 1.6 vs. 6.8 ± 1.6, $P < 0.05$) than female patients in the non-sarcopenic group (*Table 2*). Only peak VO_2/HR and BMI significantly differed between the two groups in both sexes. There were significant positive correlations between SMI and peak VO_2 ($r = 0.631$, $P < 0.001$), as well as between SMI and peak VO_2/HR ($r = 0.683$, $P < 0.001$) (*Figure 1A*). Moreover, there were significant positive correlations between SMI and peak watts ($r = 0.540$, $P < 0.001$), SMI and $\Delta VO_2/\Delta$work load ($r = 0.297$, $P < 0.05$), and SMI and BMI ($r = 0.770$, $P < 0.001$). Results of univariate correlation analyses are shown in *Table 1B*.

Table 3 shows the results of multiple linear regression analyses with peak VO_2/HR as dependent variable. The linear regression models show that SMI is an independent determinant of peak VO_2/HR after adjustment for potential confounders (age, sex, baPWV, hypertension, dyslipidemia, diabetes mellitus, coronary artery disease, chronic HF, atrial fibrillation, and treatment with beta-blockers; $B = 1.561$; $P < 0.001$).

Exercise capacity after exclusion of potential confounders

Moreover, after excluding participants who had atrial fibrillation and those being treated with beta-blockers from the analyses, we performed parallel statistical analyses of the data from the remaining 42 participants (mean age 78 years, 26% men). Of these 42 participants, 15 (36%) were in the sarcopenic group, and 27 (64%) were in the non-sarcopenic group. The results of this subpopulation were similar to those obtained from all 63 subjects; there were significant positive correlations between SMI and peak VO_2/HR ($r = 0.697$, $P < 0.001$), and patients in the sarcopenic group had significantly lower peak VO_2/HR (mL/beat) values compared with patients in the non-sarcopenic group (6.2 ± 1.7 vs. 7.7 ± 2.2, $P < 0.05$).

Follow-up assessment

The assessment after 4 months of follow-up using data from 47 participants, we found that there was still a significant positive correlations between SMI and peak VO_2/HR ($r = 0.567$, $P < 0.001$). Twenty-seven subjects were in the SMI-increasing group, and 20 subjects were in the SMI-decreasing group. There was significant positive correlations between percent change of SMI and percent change of peak VO_2/HR ($r = 0.305$, $P < 0.05$) (*Figure 1B*).

Figure 1 (A) Statistically significant positive correlation between skeletal muscle mass index and peak oxygen pulse ($r = 0.683$, $P < 0.001$) in a population of 63 chronically ill older adults. (B) Statistically significant positive correlation between per cent change of skeletal muscle mass index and per cent change of peak oxygen pulse ($r = 0.305$, $P < 0.05$) in a population of 47 chronically ill older adults after 4 months of exercise training.

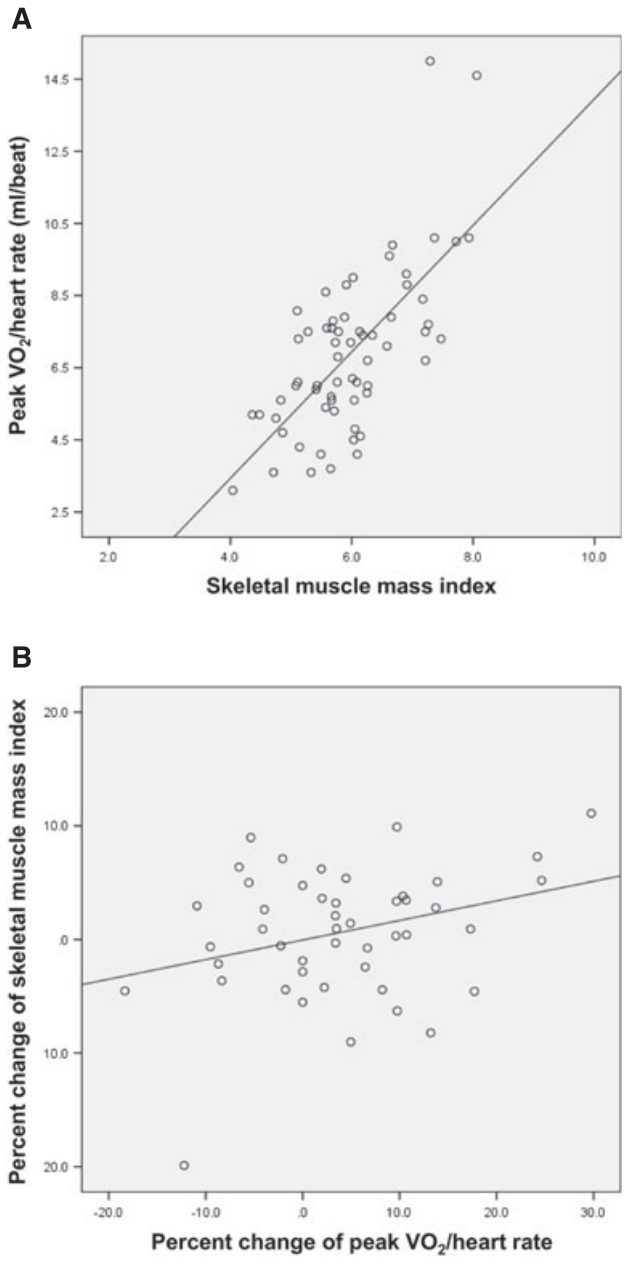

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Table 3 Multiple linear regression analysis with peak VO_2/HR as the dependent variable

	B	β	*P* value	LCI	UCI
Skeletal muscle mass index	1.561	0.625	<0.001	1.031	2.091
Age	−0.103	−0.304	<0.05	−0.174	−0.033
Sex	−1.054	−0.207	n.s.	−2.158	0.051
R^2 = 0.615					

B, regression coefficient; LCI, lower 95% confidence interval; peak VO_2/HR, peak oxygen uptake/heart rate; UCI, upper 95% confidence interval.
Adjusted for conventional risk factors (age, sex, brachial-ankle pulse wave velocity, hypertension, dyslipidemia, diabetes mellitus, coronary artery disease, chronic heart failure, atrial fibrillation, and treatment with beta-blockers) in addition to peak VO_2/HR.
P values were calculated using Student's *t*-test.

Discussion

Our study using data from unselected outpatients a geriatric outpatient clinic in Japan shows that 37% of subjects presented with reduced skeletal muscle mass that fulfills the criteria of sarcopenia. Similarly, previous study reported that the prevalence rate of sarcopenia for community-dwelling Japanese women was less than 7% for ages 60–69 years, and 24% for ages 70–80 years, and the prevalence rate of sarcopenia for community-dwelling Japanese men was less than 33% for ages 60–69 years, and 47% for ages 70–85 years.[11]

We also showed that skeletal muscle mass assessed using DEXA scanning was a major determinant of exercise capacity in elderly subjects, and this fact remained true after restricting the analysis to those without beta-blocker use and those without atrial fibrillation.

Skeletal muscle mass remained a major predictor of exercise capacity in both groups and determines the level of exercise that can be achieved in either group, even though sarcopenic subjects had overall lower peak VO_2 values than non-sarcopenic subjects.

The loss of muscle mass that occurs with ageing is clinically important because it leads to diminished muscle strength, reduced exercise tolerance, and a decreased quality of life.[12] In the present study, SMI was positively correlated with VO_2. This suggests that there is a relationship between muscle wasting and exercise intolerance. However, ageing-related muscle wasting is thought to be sex-dependent. In the present study, the only CPET parameter that was significantly correlated with SMI in both sexes was peak VO_2/HR.

In general, peak VO_2/HR is calculated using the Fick principle:

$$\text{Peak } VO_2/\text{HR} = \text{Stroke Volume (SV)} \times \text{arterial-venous oxygen difference } (AVO_2\text{diff}).$$

Peak VO_2/HR strongly correlates with peak stroke volume,[13] and therefore, it is considered an index of SV. Moreover, it was previously reported that peak AVO_2diff did not change after exercise training in either the young or in older adults.[14] Based on the Fick principle and this previous report, our results suggest that a reduction in SMI is one of the most important factors affecting the deterioration of peak SV.

Recently, the relationship between sarcopenia and cardiovascular disease has been recognized to be of a great importance in super-ageing societies. Both sarcopenia and chronic HF are highly prevalent in advanced ageing societies.[1,4] In particular, HFpEF has received much attention in recent years because of its high prevalence among older adults.[15] It has been reported that HFpEF is associated with reduced lean body mass,[5] and exercise intolerance is a hallmark of both sarcopenia and HFpEF.[16,17] The association between exercise intolerance and a lower peak VO_2 is explained by the Fick principle. However, our finding that peak VO_2/HR, an index of peak SV correlated with SMI, suggests, for the first time, a relationship between cardiac functional reserve and muscle wasting. This may be the case with the exercise intolerance in patients with HFpEF, which Phan *et al*. attributed to deterioration in peak SV.[18] On the other hand, Dhakal *et al*. reported that a reduction in peak AVO_2diff was the cause of the exercise intolerance in HFpEF,[19] although previous studies showed no changes in peak AVO_2diff with ageing.[13]

Both muscle wasting and HFpEF are associated with exercise intolerance. Muscle wasting is associated with a reduction in peak SV, whereas HFpEF is associated with a reduction in peak SV and/or peak AVO_2diff. Thus, muscle wasting in community-dwelling older adults might be one of several possible phenotypes of ageing, which may subsequently develop to HFpEF.

There are several potential mechanisms that may underlie the relationship between muscle wasting and deterioration of cardiac function. It was known that the most evident metabolic explanation for muscle wasting is an imbalance between protein catabolism (e.g. members of the ubiquitin–proteasome system, myostatin, and apoptosis inducing factors) and anabolism (e.g. members of the ubiquitin–proteasome system, myostatin, and apoptosis inducing factors).[20,21] Even more, it was known that the muscle wasting in HF is also an imbalance between protein catabolism and anabolism.[22] Recently, Mangner and colleagues show an animal model in that the antioxidative and metabolic capacities are heterogeneous in their response to chronic HF between the diaphragm and quadriceps, but similar activation of protein degradation pathways (e.g. the ubiquitin–proteasome system) was evident in both muscles.[23] Ubiquitin–proteasome system is known as the system that induces degradation of sarcomeric proteins including cTnI,[24] myosin heavy chain,[25] and myosin-binding protein.[26] These changes occur in both skeletal muscle and cardiomyocytes. In addition, MuRF-1 affects fatty acid and

glucose oxidation, as well as mitochondrial function in cardiomyocytes.[27] These mechanisms might underlie the relationship between muscle wasting and cardiac function, in both of deconditioning and reconditioning.

It was known that peripheral circulation significantly contribute to exercise intolerance in patients with chronic HF.[28] Therefore, we evaluated baPWV as a parameter of peripheral circulation in this study. We found that there is a low negative correlation between SMI and baPWV, and there is no difference of baPWV between sarcopenic group and non-sarcopenic group (*Table 3*). Furthermore, in multiple linear regression analyses, no relation was found between baPWV and each of peak VO_2/HR and SMI (*Table 3*). This might be due to the difference of participant's characteristics between chronic HF patients in previous report[28] and community-dwelling older adults in this study.

This study had several limitations. Firstly, we did not measure the biomarker which related with ubiquitine–proteasome system. Secondly, we did not measure SV directly.

In conclusion, peak VO_2/HR (an index of stroke volume at peak exercise) was strongly associated with skeletal muscle mass. SMI was an independent determinant of peak VO_2/HR after adjustment for potential confounders. These results suggest that there is a bidirectional relationship between muscle wasting and cardiac function in community-dwelling older adults. A large number of longitudinal studies are needed to evaluate cardiac function over time and to prove a causal relationship between SMI and peak VO_2/HR.

Conflict of interest

None declared.

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