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Left Ventricular Mass: Correlation with Fatness, Hemodynamics and Renal Morphology

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Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background: Left ventricular mass (LVM) is correlated with body composition and central hemodynamics as well as kidney function. Recently, fat-free mass has been considered to be more strongly correlated with LVM in comparison to other descriptors of fatness. We therefore address the question of whether comprehensive descriptors of fatness, central hemodynamics and renal characteristics demonstrate the association with left ventricular mass in healthy non-obese population.

Material/Methods: 119 healthy non-obese subjects (53 females, 66 males, mean age 50 yrs) were evaluated. Central hemodynamics was measured by Pulse Wave Analysis, left ventricular mass was assessed by echocardiography, fatness was evaluated by anthropometry, bioimpedance, and ultrasound.

Results: Left ventricular mass index (LVMI) correlated to the same extent with central and peripheral blood pressure but not with descriptors of wave reflection. Fat-free mass as well as intraabdominal fat correlated to a similar extent with LVMI. Kidney morphological characteristics indexed to body surface area were associated inversely and independently with LVMI.

Conclusions: Comprehensive assessment of fatness reinforced the concept that intraabdominal fat compartment is strongly correlated with left ventricular mass. Descriptors of wave reflection are not associated with left ventricular mass. The interrelationsh between kidney morphology and LVMI indicates that such associations may be a biologically plausible phenomenon.

MeSH Keywords: Abdominal Fat • Hemodynamics • Kidney • Ultrasonography • Ventricular Function, Left

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Background

The left ventricular mass (LVM) is an independent risk factor for cardiovascular complications with positive correlation between LVM and risk [1]. In this association, a continuum, without a clear-cut threshold can be observed. Various hemodynamic factors as well as body composition are correlated with LVM [2–5]. The majority of published articles reported a positive correlation between body mass index (BMI) and left ventricular (LV) mass [6,7]. It was also suggested that fat-free mass (FFM), but not adipose mass, is more strongly related to left ventricular mass [8]. Blood pressure (BP) represents a major factor influencing LVM. However, due to the phenomenon of pulse pressure amplification, blood pressure varies throughout the arterial bed. It was suggested that central hemodynamics contributes much more strongly to LVM than peripheral blood pressure [9]. The association between left ventricular mass and renal function is also a well-appreciated phenomenon [10–12]. However, a comprehensive evaluation of all these descriptors in relation with left ventricular mass in a single population was not performed. We therefore address the question of whether various measures of fatness, central hemodynamics and renal morphology are associated with left ventricular mass in healthy non-obese population.

Material and Methods

One hundred and nineteen healthy subjects were evaluated (53 women, 66 men, mean age 50 yrs). Before inclusion into

the study, the subjects were screened for cardiac risk factors. Exclusion criteria were: hypertension, diabetes mellitus or known cardiovascular disease. None of the subjects was on medication. Their health status was evaluated with a detailed history-taking and physical examination, resting standard 12-lead ECG and brachial blood pressure measurement in seated position on both arms (M-5, Omron Healthcare Co, Ltd, Kyoto, Japan). Body mass index (BMI) was presented as weight (kg) divided by height^2 (m). Waist circumference was obtained halfway between the lower rib and the iliac crest, and hip circumference was measured at the level of the greater trochanter.

Measurements of the hemodynamics were performed in a temperature-controlled (21–22°C) room with the subjects supine, after a 10-minute rest.

The University Ethics Committee approved the study protocol, and written informed consent was obtained from all the participants.

Ultrasound interpretation

The Aloka Alpha Prosound 7 (Aloka Ltd, Co, Japan) with 3.5 MHz convex transducer was used to evaluate renal morphology by a radiologist unaware of the results of the hemodynamic study. The renal length, width and thickness of the parenchyma and cortex were evaluated in the longitudinal plane. The thickness of the kidneys was measured in the transverse plane. All patients were examined in the supine position. We assessed the renal parenchyma and cortex in the middle region of the kidney. The thickest part of the parenchyma was measured between the renal capsule and the border of the renal sinus. The cortex was measured between the renal capsule and the upper pole of the renal pyramid. The measurements of the cortex and parenchyma were taken perpendicular to the renal capsule. Intra-abdominal and subcutaneous fat were estimated in the transverse plane during a shallow exhale at the point of aortic bifurcation. Intra-abdominal fat was measured between the abdominal fascia and the posterior wall of the aorta.

Echocardiography

Echocardiogram studies were performed with the CV-70 (Siemens) imaging system. Images were obtained using harmonic imaging with the patient in the partial left lateral decubitus position and evaluated by 2 experienced observers, blinded to hemodynamic and renal studies. Left ventricular end-diastolic diameter (LVEDD), interventricular septal thickness and posterior wall thickness (PWT) were measured at end-diastole using the leading-edge to leading-edge method. Left ventricular mass was calculated according to the Devereux formula. Left ventricular mass index was defined as left ventricular mass divided by body surface area (LVM/BSA, g/m^2)

Pulse wave analysis (PWA) of central pressure waves

Radial pressure waveform and on-line reconstruction of the aortic waveform was obtained by an applanation tonometer (CBM 7000, Colin Medical Instruments, Japan) connected to the Sphygmocor Mx validated system (AtCor Medical, Australia). Averaged peripheral and central (aortic) waveforms were generated (from 10 sequential pulse waveforms) and quantitatively characterized by means of pulse wave analysis. Central augmentation index (cAIx), was calculated as the difference between the second and the first systolic peak on the central arterial waveform and expressed as the percentage of the central pulse pressure (Figure 1). Augmentation pressure (AP) is defined as the height of central systolic pressure above the first systolic shoulder in the arterial pulse waveform.

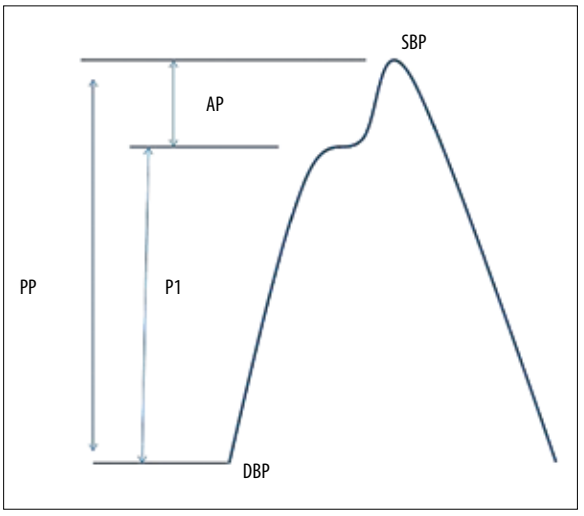

Figure 1. In the aortic pressure waveform the following descriptors are shown: central pulse pressure (PP), augmentation pressure (AP) and pressure at first systolic peak (P1). SBP – systolic blood pressure, DBP – diastolic blood pressure.

Fatness assessment

A bio-impedance analyzer (MC180MA, Tanita Corp USA) was used to assess the fat content as a proportion of total body mass. Bio-impedance analysis was performed with multi-frequency technology.

Statistical analysis

The obtained results are expressed as the mean ±SD. To measure the strength of linear association between variables the Pearson correlation coefficient was calculated. The association of the left ventricular mass index with the other clinical variables was examined with the use of multivariable regression. All tests were two-sided. The statistical analyses were performed using Statistica 8.0 (Stat Soft Inc, USA), and the statistical significance was set at $p<0.05$.

Results

As outlined in Table 1, the study group consisted of 119 non-obese subjects (mean age 50 yrs).

Hemodynamic factors influencing left ventricular mass

In the studied group peripheral systolic and diastolic blood pressure (BP) correlated with LVMI ($r=0.25$, $p=0.007$ and

Table 1. Clinical characteristics of study participants.

Characteristics	
Age (yrs)	50±1
M/F	53/66
BMI (kg/m^2)	25±0.4
WHR	0.9±0.01
LVMI (g/m^2)	85±2
Intra-abdominal fat (cm)	6.4±0.01
Subcutaneous fat (cm)	1.5±0.06
Fat-free mass (kg)	55±1
Fat percentage (%)	18.9±0.7
Creatinine Clearance (Cockcroft-Gault) (mL/min)	109±3
Cholesterol (mg/dL)	208±4
Glucose (mg/dL)	86±2
Peripheral SBP (mmHg)	121±1
Peripheral DBP (mmHg)	74±1
Central SBP (mmHg)	111±1
Central DBP (mmHg)	75±1
BP mean (mmHg)	91±1
BP at P1 (mmHg)	101±1
Central AIx@75 (%)	27±1
Central AP (mmHg)	11±1

M – male; F – female; BMI – body mass index; WHR – waist/hip ratio; LVMI – left ventricular mass index; SBP – systolic blood pressure; DBP – diastolic blood pressure; BPmean – mean blood pressure; BP – blood pressure; AIx – augmentation index; AP – augmentation pressure.

r=0.28, p=0.002, respectively, Table 2). A similar association was found between central systolic blood pressure (SBP) as well as diastolic BP (DBP) and left ventricular mass index (r=0.24, p=0.009 and r=0.28, p=0.002, respectively). Central BP at P1 was also significantly correlated with LVMI (r=0.27, p=0.002). In contrast, neither central augmentation index nor augmentation pressure correlated significantly with LVMI (r=–0.09, p=0.36 and r=–0.001, p=0.99, respectively).

Fatness descriptors in relation with left ventricular mass

Percent body fat correlated significantly but weakly with LVMI (r=0.19, p=0.048 Table 3). Fat-free mass showed a strong positive correlation with LVMI (r=0.46, p<0.0001). Intra-abdominal fat correlated to a similar extent with left ventricular mass index (r=0.42, p<0.0001). However, subcutaneous fat showed no significant correlation with LVMI (r=–0.07, p=0.44). WHR, waist circumference and

Table 2. Correlation of peripheral and central BP indices with LVMI.

BP characteristics	Correlation coefficient (p-value)	
Peripheral SBP	0.25	(p=0.007)
Peripheral DBP	0.28	(p=0.002)
Central SBP	0.24	(p=0.009)
Central DBP	0.28	(p=0.002)
Central BP at P1	0.27	(p=0.002)
Central AIx	–0.09	(p=0.36)
Central AP	–0.001	(p=0.99)

LVMI – left ventricular mass index; SBP – systolic blood pressure; DBP – diastolic blood pressure; BP – blood pressure; AIx – augmentation index; AP – augmentation pressure.

Table 3. Correlation of fatness measures with LVMI.

Measures of fatness	Correlation coefficient (p-value)	
% fat	0.19	(p=0.048)
Intraabdominal fat	0.42	(p<0.0001)
Subcutaneous fat	–0.07	(p=0.44)
WHR	0.33	(p=0.003)
Waist circumference	0.4	(p<0.0001)
FFM	0.46	(p<0.0001)
BMI	0.35	(p<0.0001)

LVMI – left ventricular mass index; WHR – waist/hip ratio; FFM – fat-free mass; BMI – body mass index.

Table 4. Kidney morphology and creatinine concentration in relation to LVMI.

Characteristics	Correlation coefficient (p-value)	
Kidney length/BSA	–0.29	(p=0.001)
Kidney thickness/BSA	–0.31	(p=0.0006)
Creatinine concentration	0.12	(p=0.1)

BSA – body surface area; LVMI – left ventricular mass index.

BMI correlated significantly with LVMI (r=0.33, p=0.003; r=0.4, p<0.0001 and r=0.35, p<0.0001, respectively).

Association between kidney morphological characteristics, creatinine and left ventricular mass

As demonstrated in Table 4, creatinine clearance did not correlate with LVMI (r=0.12, p=0.1) while kidney length and thickness indexed to body surface (BSA) showed a significant and negative association with LVMI (r=–0.29, p=0.001 and r=–0.31, p=0.0006, respectively).

Discussion

In this study, we confirmed that fat-free mass obtained with bioimpendance was more strongly related to left ventricular mass index than WHR, waist circumference and BMI. However, intraabdominal fatness estimated with ultrasound was correlated with LVMI to a similar extent as FFM. Central blood pressure as well as peripheral BP hemodynamic profile were associated with LVMI while the descriptors of wave reflection showed no association with left ventricular mass. Moreover, left ventricular mass index was inversely associated with indexed renal length and thickness.

It is generally accepted that obesity is associated with increased mortality due to cardiovascular complications [13,14]. Despite studies showing that obesity is related to left ventricular mass even after controlling for age and blood pressure, several investigators challenged this common opinion. In "Strong Heart Study" the investigators demonstrated that left ventricular mass was more strongly correlated with FFM than with adipose mass, waist/hip ratio or body mass index [8]. The indexation of LV mass to fat-free mass was also suggested as a better predictor of left ventricular hypertrophy [15]. None of these studies used comprehensive methods to evaluate body fatness. In our current study body fatness was evaluated by anthropometry, bioimpedance (BIA) and ultrasonography. Similarly to the report of Bella et al. [8] FFM assessed by BIA was much more strongly correlated with LVMI than percent body fat or traditional descriptors of fatness like WHR or waist circumference. However, when the visceral fat compartment was estimated by ultrasound, the descriptor of intraabdominal fat was correlated with LV mass to the same extent as FFM. This observation reinforces the concept that body fatness is in a very close relation with left ventricular mass. Moreover, it is appreciated that different fat depots (subcutaneous, abdominal visceral, total body fat) have divergent functional meanings. Subjects with BMI even within normal limits but with higher levels of visceral adipose tissue (VAT) are frequently characterized by insulin-resistance, prothrombotic and proinflammatory profiles [16]. Higher levels of VAT are also associated with low cardiorespiratory fitness and elevated blood pressure [17]. Thus body composition traits may inversely influence LV mass.

Central blood pressure and hemodynamic profile are superior to peripheral (brachial) BP in risk assessment of future cardiovascular complications. Several other pulse wave descriptors derived from pulse wave analysis, e.g. augmentation index, were shown to better predict left ventricular mass reduction than cuff pressure [18]. In our current study, LVMI correlated with systolic and diastolic BP assessed at periphery as well as central BP. Aortic blood pressure was associated with LV mass to a similar extent as brachial BP. Moreover, pulse wave reflection indices like augmentation index and augmentation pressure were not associated with LV mass. These observations corroborate earlier studies [19,20]. Deague et al. [19] examined the physiological relationship between central vascular hemodynamics and left ventricular structure in healthy subjects and found no relationship between LVMI and AIx. DeLoach et al. [20] evaluated central BP in Afro-American adolescents in relation to LV mass. Central augmentation index in that population was not correlated with LVMI.

It is suggested that cardiovascular risk is increased even in the earliest stage of renal damage. Moreover, diminished glomerular filtration rate or the presence

of albuminuria independently predicts cardiovascular complications [21,22]. It is also accepted that renal morphometric criteria are related to kidney function [23,24]. One of the current hypotheses states that smaller kidneys are characterized by a diminished number of nephrons which may contribute to a worse function and to the development of primary hypertension. Currently no clinical methods allow to estimate the number of nephrons in a living subject. However, it was shown that kidney size influences serum creatinine level, at least in normal pediatric populations [23]. In our present study, renal length and thickness indexed for BSA were inversely associated with LVMI. Thus even in a healthy population with a normal creatinine concentration a link exists between kidney morphometry and LV mass, which suggests that a biologically plausible mechanism may be involved.

Conclusions

In summary, this study showed that intraabdominal fat is associated with LV mass to a similar extent as fat-free mass, while the indices of central blood pressure profiles are similarly correlated to LVMI as peripheral blood pressure descriptors and that indexed measures of renal length and thickness are related to LV mass.

Conflicts of interest

The authors declare no conflicts of interest.

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