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Research Article

Indexing cardiac parameters in echocardiographic practice: Do estimates depend on how weight and height have been assessed? A study on left atrial dilatation

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Abstract

We examined the difference between self-reported and measured height and weight in detecting echocardiographic left atrial dilatation (LAD), as defined by LA diameter indexed to body size parameters in an outpatient population referred to echocardiographic laboratories for routine examination. LAD was defined by 2 criteria: (1) LA diameter indexed to height greater than 24 mm/m; (2) LA diameter indexed to body surface area greater than 23 mm/m^2. Prevalence of LAD was calculated by indexing LA diameter to both self-reported and measured anthropometric values. In the whole population, LAD tended to be underestimated when LA diameter was indexed to self-reported compared with measured values, by 3.6% according to criterion 1 (26.4% versus 30.0%, $P < .001$) and by 0.6% according to criterion 2 (21.1% versus 21.6%, $P =$ not significant). The difference between LAD estimates was more pronounced in older than in younger patients, either by criterion 1 (6.4% versus 1.6 %, $P < .001$) or by criterion 2 (2.1% versus 0.1%, $P < .001$). The error is related to demographic characteristics of patients and is more pronounced when LA diameter is normalized to height. J Am Soc Hypertens 2011;■(■):1–7.

Keywords: Body height; body weight; self-reporting; echocardiography; left atrial dilatation.

Introduction

In the past 2 decades, echocardiographic left atrial (LA) dimensions have been extensively investigated as markers of diastolic dysfunction and cardiovascular risk.[1–3]

LA dilatation (LAD) has been shown to be a cardiac phenotype related to aging,[4] systemic hypertension,[5] and electrocardiographic or echocardiographic left ventricular

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hypertrophy (LVH) in different clinical settings.[6,7] An independent association between echocardiographic LA diameter or volume and incident atrial fibrillation,[8,9] stroke,[10,11] cardiovascular events, and death[12,13] has been extensively described.

The relationship between LAD and poor clinical outcomes is supported by the biological evidence that LA acts as a volume sensor of the heart and that its dilatation reflects a sustained elevation in LV filling pressure secondary to systolic and/or diastolic LV dysfunction.[14] Moreover, LAD is usually associated with structural (ie, fibrosis) and electrical alterations that may induce atrial fibrillation, a condition contributing to LV pressure increase.[15,16]

In a seminal paper by Tsang et al[17] aimed at investigating the role of subclinical echocardiographic abnormalities in predicting cardiovascular outcomes (ie, first myocardial infarction, coronary revascularization, congestive heart failure, atrial fibrillation, stroke, and cardiovascular deaths) in a community-based population of elderly patients, LAD turned out to be the major predictor of outcomes before LVH and systolic and diastolic dysfunction, in ranking order.

Current evidence supports the view that echocardiographic LAD should be extensively investigated so as to improve cardiovascular risk stratification in daily practice.

Cardiac parameters, including LA size, LV mass, and aortic root, are commonly normalized to body surface area (BSA) or height; in clinical practice, however, body size values are frequently reported by the patient rather than measured in the echocardiographic laboratory. In the present study, we investigated the impact of self-reported and measured weight and height on the estimates of LAD prevalence based on LA diameter indexed to either BSA or height in a large cohort of subjects referred to outpatient echocardiographic laboratories for routine examination.

Methods

Setting

Fifteen outpatient echocardiographic laboratories of the network of the Italian Society of Hypertension were asked to participate in the project. Ten laboratories adhered to the study and were requested to enroll a minimum of 100 outpatients of either gender, who were older than 18 years, consecutively referred to echocardiographic laboratories by their general practitioners, and whose written prescription was used to identify the clinical indications for the examination. Nine of 10 laboratories (Appendix 1) effectively enrolled the requested number of patients. Basic characteristics of these centers were the following: 7 served as outpatient echocardiographic laboratories within university departments (6 of internal medicine and 1 of clinical cardiology) and the remaining 2 served in hospital cardiology units. Details of the protocol have been previously reported.[18] Briefly, no exclusion criteria were defined for the enrollment with the exception of patients with alterations of LV geometry impairing a reliable estimate of LV mass. Information about patients' demographic data, including self-reported weight and height, medical history, and medications, were collected at the echocardiography laboratories by a structured questionnaire administered by the attending physicians. In particular, participants were asked to declare their body weight and height. Self-reported body weight was collected with the question, ''What is your current body weight?'' in kilograms. Self-reported height was obtained with the question, ''What is your height?'' in centimeters.

Measurements

Body weight was recorded to the nearest 100 g using a calibrated electronic scale with the subjects wearing indoor clothing without shoes. Height was recorded to the nearest 0.5 cm using a standardized wall-mounted height board.

Clinic blood pressure (BP) was measured with a mercury sphygmomanometer using an appropriately sized cuff; measurements were performed in the echocardiographic laboratories after the subjects had rested for 3 to 5 minutes in the sitting position. Three measurements were taken from the nondominant arm, at 1-minute intervals, and the average was used to define a patient's representative values.

Echocardiography

Echo and Doppler examinations were performed in each participating center according to a standardized protocol as previously described. In brief, M-mode, 2-dimensional, and Doppler echocardiographic examinations were carried out by high-performance instruments equipped with 2.0- to 2.5-MHz imaging transducers. In particular, end-diastolic (d) and end-systolic (s) LV internal diameters (LVID), interventricular septum thickness (IVS), and posterior wall thickness (PW) were calculated from 2-dimensionally guided M-mode tracings recorded at a speed of 50 to 100 cm/s, and measured during 3 to 5 consecutive cycles according to the Penn convention. LV mass was estimated by Devereux's formula $(1.04\ (IVSd + PWd - LVIDd)^3 - LVIDd^3] -13.6)$[19] and normalized to BSA. LVH was defined as LV mass index equal to or higher than 116 g/m^2 in men and 95 g/m^2 in women.[20] LA size was determined according to the American Society of Echocardiography guidelines[20] in the parasternal long-axis view, using a leading edge–to–leading edge measurement of the maximal distance between end-systolic posterior aortic root wall and posterior LA wall. LA diameter was normalized to BSA or height, based on either measured or self-reported weight and height values. LAD was defined in both genders as (1) LA diameter indexed to height greater than 24 mm/m; and (2) LA diameter indexed to BSA greater than 23 mm/m^2. These cut points correspond to the 95th percentile in a group of 1054 subjects with normal office and out-of-office BP (ie, home and ambulatory BP) enrolled in the Pressioni Monitorate E Loro Associazioni (PAMELA) study.[21]

Two files per patient were e-mailed to the Clinical Research Center, Istituto Auxologico Italiano, University of Milano-Bicocca, acting as the coordinating center for the final analysis: (1) the questionnaire containing demographic and clinical data, and (2) the echocardiographic diagnostic report.

The protocol of the study was approved by the ethics committee of the coordinating center (Istituto Auxologico Italiano and University of Milano-Bicocca).

Statistical Analysis

Statistical analysis performed by the SAS System (version 6.12; SAS Institute Inc., Cary, NC) included calculation of means ± SD for continuous variables and percentages for categorical variables. Mean values were compared by Student *t* test for independent samples.

Categorical data were analyzed by the chi-square test or the Fischer's exact test when appropriate; *P* less than .05 was considered statistically significant.

Results

A total of 2042 patients were recruited between January and June 2009; 99 of these patients were excluded because of incomplete echocardiographic reports. Thus, 1943 subjects were eligible for the final analysis and their clinical characteristics are reported in Table 1.

Briefly, 993 subjects were males (51.1%), mean age was 58 ± 17 years, and mean systolic BP (SBP) and diastolic BP (DBP) were 134 ± 18 and 80 ± 11 mm Hg, respectively. Prevalence rates of hypertension (defined as SBP ≥140 mm Hg and/or DBP ≥90 mm Hg in untreated subjects or current antihypertensive treatment) and LVH were 48.9% and 46.2%, respectively; 14.4% of the subjects were current smokers (>3 cigarettes/day), and 7.1% had type 2 diabetes mellitus (ie, fasting serum glucose level ≥6.99 mmol/L, and/or current therapy with oral hypoglycemic agents and/or insulin).

Weight was underreported by an average of 0.8 kg, whereas height was overreported by 3.6 cm. The prevalence of obesity (body mass index ≥30 kg/m^2) was underestimated by self-reported compared with measured values (17.4% versus 23.7%, $P < .001$); BSA was similar by both values (1.81 versus 1.80 cm^2).

As shown in Table 2, LA diameter indexed to self-reported height (22.5 mm/m) was significantly lower than that indexed to measured height (22.8 mm/m, $P < .01$). This trend was no more evident when LA diameter was indexed to BSA: 20.8 mm/m^2 by self-reported values and 20.9 mm/m^2 by measured values, respectively, P = not significant).

Figure 1 depicts prevalence rates of LAD according to LA diameter indexed to both BSA and height based on measured and self-reported values in the whole study population. LAD remained undetected in as many as 70 patients (3.6%, $P < .001$) when LA diameter was indexed

Table 1
Clinical characteristics of the study population as a whole and divided by age

Variables	All Subjects (n = 1943)	<65 Years (n = 1141)	≥65 Years (n = 802)
Age, y	57.8 ± 16.9	47.0 ± 13.5	73.1 ± 5.7*
Gender , % males	51.1	55.0	45.5*
Clinic SBP, mm Hg	134 ± 18	130 ± 17	140 ± 17*
Clinic DBP, mm Hg	80 ± 11	81 ± 11	79 ± 10*
Pulse pressure, mm Hg	54 ± 15	49 ± 12	61 ± 15*
Clinic heart rate, beats/min	73 ± 11	73 ± 11	73 ± 12
$Weight_m$ (measured), kg	73.5 ± 15.8	74.6 ± 16.6	72.0 ± 14.0*
$Weight_s$ (self-reported), kg	72.7 ± 15.3	73.6 ± 16.2	71.3 ± 13.4*
$Height_m$ (measured), cm	164 ± 10.0	167 ± 10	161 ± 9.5*
$Height_s$ (self-reported), cm	167 ± 9.4	169 ± 10	164 ± 8.5*
BSA_m (measured), m^2	1.80 ± 0.22	1.83 ± 0.23	1.75 ± 0.20*
BSA_s (self-reported), m^2	1.81 ± 0.21	1.83 ± 0.22	1.77 ± 0.19*
Obesity from measured values, %	23.7	21.8	29.2*
Obesity from self-reported values,%	17.4	17.4	17.5
Current smokers, %	14.4	19.1	7.2*
Diabetes, %	7.1	3.7	10.4*
Hypertension, %	48.9	39.8	61.5*

Data are shown as means ± SD or percent.
BSA, body surface area; DBP, diastolic blood pressure; SBP, systolic blood pressure.
* $P < .001$ (at least) versus subjects <65 years.

Table 2
Echocardiographic variables in the study population as a whole and divided by age

	All Subjects (n = 1943)	<65 Y (n = 1141)	≥65 Y (n = 802)
LVIDd, mm	48.3 ± 5.5	48.1 ± 5.3	48.6 ± 5.7
LVIDs, mm	29.5 ± 6.1	29.1 ± 5.5	29.8 ± 6.7
IVSTd, mm	10.1 ± 1.9	9.8 ± 1.9	10.6 ± 1.7*
PWTd, mm	9.4 ± 1.5	8.9 ± 1.4	9.5 ± 1.4*
LVRWT	0.40 ± 0.07	0.39 ± 0.06	0.42 ± 0.07*
AR diameter, mm	32.8 ± 5.0	32.2 ± 5.0	33.7 ± 4.8*
LA/BSA_s (self-reported), mm/m^2	20.8 ± 3.6	19.7 ± 2.9	22.4 ± 3.8*
LA/BSA_m (measured), mm/m^2	20.9 ± 3.7	19.7 ± 2.9	22.7 ± 4.0*
LA/h_s (self-reported), mm/m	22.5 ± 3.9	21.3 ± 3.3	24.2 ± 4.0*
LA/h_m (measured), mm/m	22.8 ± 3.6	21.5 ± 3.4	24.8 ± 4.2*
LVEF, %	66.0 ± 8.2	67.6 ± 7.8	63.8 ± 8.3*
E velocity, cm/sec	71.2 ± 19.9	73.3 ± 18.9	68.2 ± 20.9*
A velocity, cm/sec	71.2 ± 22.4	62.6 ± 17.8	83.1 ± 22.7*
E/A ratio	1.10 ± 0.47	1.27 ± 0.47	0.86 ± 0.35*
LVM, g	195.7 ± 69.9	186.7 ± 70.1	208.2 ± 67.6*
LVH, %	46.2	34.3	63.3*

Data are shown as means ± SD or percent.

A, late diastolic mitral flow; AR, aortic root; E, early diastolic mitral flow; IVSTd, interventricular septum thickness in diastole; LA, left atrium; LVEF, left ventricular ejection fraction; LVH, left ventricular hypertrophy; LVIDd, left ventricular internal diastolic diameter; LVIDs, left ventricular internal systolic diameter; LVM, left ventricular mass; LVRWT, left ventricular relative wall thickness; PWTd, posterior wall thickness in diastole.

* $P < .001$ (at least) versus subjects <65 years.

to self-reported height; LAD was underestimated in only 11 subjects (0.6%, P = not significant) when LA diameter was normalized to self-reported values for BSA.

Elderly Patients

Clinical and echocardiographic findings in patients categorized according to age (<65 and ≥65 years) are reported in Tables 1 and 2. As expected, female gender and cardiovascular risk factors such as hypertension, obesity, and diabetes were more prevalent in the elderly subgroup. Differences between measured height, obesity, LA diameter indexed to height and BSA, prevalence rates of LAD, and the corresponding values based on self-reported data were significantly greater in the elderly than in their younger counterparts. LA diameter indexed to self-reported compared with measured height tended to underestimate LAD prevalence by 6.4% in the elderly versus 1.6% in the adult group ($P < .001$); the corresponding figures for LA diameter indexed to BSA were 2.1% and 0.1% ($P < .01$) respectively (Figure 2).

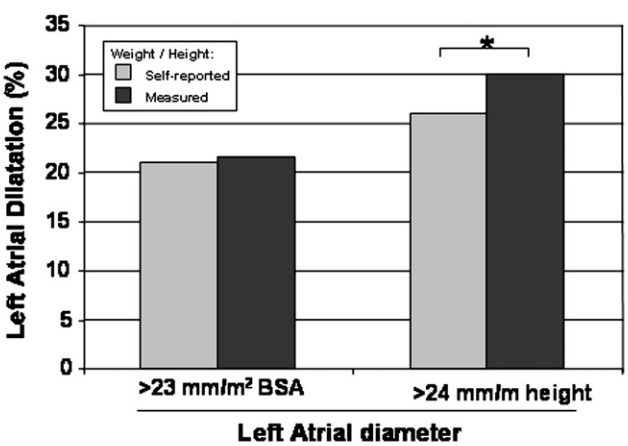

Figure 1. Prevalence rates of LA dilatation calculated according to LA diameter indexed to both BSA and height based on measured (*black columns*) and self-reported values (*gray columns*) in the whole study population. *P at least < .01 self-reported versus measured.

Discussion

The findings of this multicenter Italian survey showed that misreporting weight and height by individuals attending outpatient echocardiographic laboratories underestimated LAD prevalence by 3.6% when this cardiac phenotype was defined by LA diameter normalized to height and by 0.6% when LA diameter was indexed to BSA, according to the cut offs of the PAMELA study.[21] Notably, self-reported anthropometric data tended to misclassify LAD prevalence more in elderly than in adult patients, regardless of the indexation criteria.

Factors affecting self-reported weight and height values have been extensively investigated; bias in self-reporting depends on demographic, social, and health characteristics of a population. A meta-analysis by Gorber et al,[22] including more than 60 studies in the adult population,

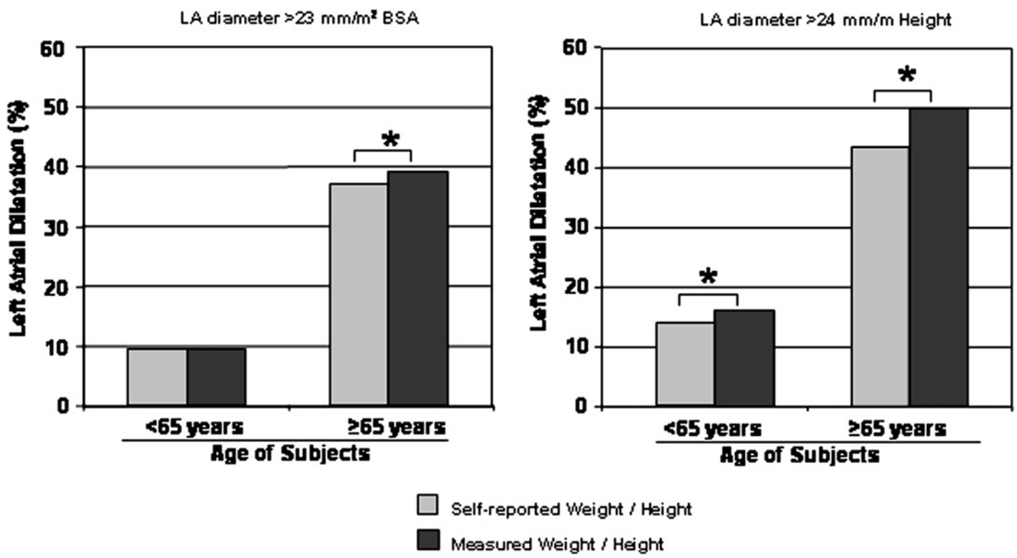

Figure 2. Prevalence rates of LA dilatation calculated according to LA diameter indexed to both BSA and height based on measured (*black columns*) and self-reported values (*gray columns*) in the adult (<65 years) and elderly subgroup (≥65 years). * *P* at least < .01 self-reported versus measured.

has shown that weight and body mass index tend to be underreported, whereas height is overreported; different trends, however, have been observed among and within the populations studied. In a recent review by Faeh et al,[23] including 5 studies carried out in Switzerland, the prevalence of obesity based on measured body mass index was markedly higher (1.6 times) than the estimates based on self-reported values; the differences tended to increase with age in both genders. Our results confirm previous evidence and extend these observations to the echocardiographic laboratory, a setting where the anthropometric parameters should be precisely assessed to scaling cardiac variables to body size. Our data indicate that both weight (–0.8 kg) and height (+2 cm) were misreported in the entire sample and that overestimation of height peaked in the elderly.

Identification of abnormal cardiac phenotypes by echocardiography, such as LVH, LAD, and systolic/diastolic dysfunction plays a pivotal role in cardiovascular risk stratification and therapeutic decision making. Methodological aspects related to this technique may affect the precision of cardiac assessment and the correct classification of patients according to subclinical organ damage. Accuracy and precision of quantitative echocardiography are related to multiple factors, including the operator's experience, the patient's echogenic characteristics, equipment technology, and reliable reading methods.[24] The current study offers a new piece of evidence in this field by showing that indexation of LA diameter to self-reported anthropometric values underestimates the attributable risk of LAD in outpatients referred for an echocardiographic examination. The magnitude of LAD underestimation was affected by 2 factors: (1) criteria for scaling LA diameter to body size; and (2) the patient's demographic characteristics. In the whole study population, LAD was misclassified by either self-reported height or weight; this phenotype, however, was underestimated by 6-fold when LA diameter was indexed to height as compared with BSA. Regardless of LA indexation criteria, LAD was underestimated in the elderly more than in the younger counterpart.

In our series, a relevant proportion of patients was found to have LAD by measured parameters: approximately 30% according to the partition value of 25 mm/m and 22% according to the 24 mm/m^2 threshold. We have previously reported a similar prevalence of LAD (23%) in a middle-aged population of uncomplicated essential hypertensive individuals included in the ETHOD registry.[5] The prevalence of LAD in the present study was higher than that reported in the Strong Heart study (16%), a population-based cohort including 2804 American Indians free of clinical cardiovascular disease.[12] The following factors may account for the higher rate of LAD in our series: ethnic-related differences; inclusion of patients referred for heart failure, ischemic heart disease, valve disease, arrhythmias, or cerebrovascular disease; and high prevalence of hypertensive individuals (approximately 50%) and elderly individuals (42%).

For a proper interpretation of our results, some additional comments are needed. First, available data about the modality of collecting an individual's body size values in echocardiographic practice are rather scanty; in particular, it is uncertain to what extent self-reported rather than measured body size values are used for indexing cardiac parameters in ultrasound laboratories. Investigating this issue by means of a questionnaire sent to 20 nonacademic outpatient echocardiographic settings randomly selected across Italy, we found that anthropometric values were measured in only 1 of 20 centers.

Second, misreporting height and weight has been shown to differ among populations; thus, our findings should not be extended to different settings. From our data, it appears that indexing LA diameter to BSA may minimize the error.

Third, a limitation of the present study is that LA size was assessed by a simple linear measurement (ie, single diameter) rather than by volume. LA diameter has been shown to be an independent predictor of cardiovascular outcome and in clinical practice may represent a valid surrogate of LA volume.

Conclusions

A reliable evaluation of cardiac chamber size and function is a major task of quantitative echocardiography; this task strongly depends on the precision and accuracy of standardized ultrasonographic procedures. Findings from the present study indicate that indexing cardiac parameters to self-reported rather than measured anthropometric values may impair the capacity of detecting an adverse cardiac phenotype such as LAD.

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