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# Aortic Root Dimension Using Transthoracic Echocardiography: Results from the Copenhagen City Heart Study

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**Findings regarding the relation between aortic size and risk factors are heterogeneous. This study aimed to generate new insights from a population-based adult cohort on aortic root dimensions and their association with age, anthropometric measures, and cardiac risk factors and evaluate the incidence of acute aortic events. Participants from the fifth examination round of the Copenhagen City Heart study (aged 20 to 98 years) with applicable echocardiograms and no history of aortic disease or valve surgery were included. Aorta diameter was assessed at the annulus, sinus of Valsalva, sinotubular junction, and the tubular part of the ascending aorta. The study population comprised 1,796 men and 2,316 women; mean age: 56.4 ± 17.0 and 56.9 ± 18.1 years, respectively. Men had larger aortic root diameters than women regardless of height indexing (p <0.01). Age, height, weight, systolic and diastolic blood pressure, mean arterial pressure, pulse pressure, hypertension, diabetes, ischemic heart disease, and smoking were positively correlated with aortic sinus diameter in the crude and gender-adjusted analyses. However, after full adjustment, only height, weight, and diastolic blood pressure remained significantly positively correlated with aortic sinus diameter (p <0.001). For systolic blood pressure and pulse pressure, the correlation was inverse (p <0.001). During follow-up (median 5.4 [quartile 1 to quartile 3 4.5 to 6.3] years), the incidence rate of first-time acute aortic events was 13.6 (confidence interval 4.4 to 42.2) per 100,000 person-years. In conclusion, beyond anthropometric measures, age, and gender, diastolic blood pressure was the only cardiac risk factor that was independently correlated with aortic root dimensions. The number of aortic events during follow-up was low.**  **(Am J Cardiol 2024;218:86−93)**

**Keywords:** aortic dilatation, aortic root dimension, echocardiography, population study

Aortic root dilatation is associated with aortic valve regurgitation[1,2] and established as an independent predictor of acute aortic dissection, a devasting and life-threatening condition.[3,4] Furthermore, aortic root size is a predictor of cardiovascular events and cardiovascular death.[5,6] Aortic root size is described to be related to multiple factors such as age, gender, genetics, and hemodynamic factors.[7,8] The identification of patients at a high risk of aortic disease, such as patients with Turner syndrome, Loeys−Dietz syndrome, and Marfan syndrome, is of major importance because periodic surveillance and timely prophylactic surgery save lives.[9] In the normal population, aortic dissection is rare and associated mostly with increasing age and uncontrolled hypertension.[10] Some studies have indicated that systolic and diastolic blood pressure are directly associated with aortic root size.[6] Other studies have found a positive correlation only between diastolic blood pressure and aortic dimension and among these studies, some even found an inverse correlation with systolic blood pressure.[8,11,12] Furthermore, hypertension cannot be considered the sole factor contributing to aortic dilatation because obesity and low-grade inflammation are associated with hypertension

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and aortic size.[7,11] Hence, more data are needed on the relation between aortic root size and hypertension, age, lifestyle, and cardiovascular risk factors. The Copenhagen City Heart study is a prospective cardiovascular population study launched in 1975.[13] Its initial aim was to describe cardiovascular risk factors and the prevalence and incidence of cardiovascular disease and hypertension in the normal population. Because echocardiographic assessments were included as parts of the study, we were able to examine the aortic size and its associations with anthropometric variables and cardiovascular risk factors, thus expanding knowledge about aortic disease in the normal population.[14] The primary aim of the present study was to assess aortic root dimensions by 2-dimensional (2D) transthoracic echocardiography in a large population-based adult cohort and investigate the relation between aortic size and age, gender, anthropometric measures, and cardiac risk factors. The secondary aim was to evaluate the incidence of acute aortic events during follow-up.

## Methods

Patients enrolled (October 2011 to March 2015) in the fifth examination round of the large-scale community-based cohort study, the Copenhagen City Heart study, constituted the study sample in this substudy. In total, 9,215 randomly sampled adults (aged ≥20 years) living in central Copenhagen (the capital of Denmark) were invited and 4,543 participated (Figure 1). Briefly, invitations were sent 3 weeks before a planned health examination. The invitations included a questionnaire and a prepaid postcard allowing the patients to confirm or change the scheduled appointment or to decline to participate. The study included questionnaires (concerning health-related parameters, socioeconomic status, and lifestyle), clinical assessment, and transthoracic echocardiography. The examinations were performed by medical specialists, medical students, and medical laboratory technicians who were trained in conducting the examination procedures.

Data on medical history and follow-up were obtained from (1) the Danish Civil Registration System, containing the unique personal identification number (given upon birth or immigration into Denmark to all Danish citizens), birth date, gender, and vital status[15] and (2) the National Patient Register, which contains data on all in-patient contacts with the Danish healthcare system from 1977 onward and, since 1995, data on outpatient and emergency room contacts as well (including diagnosis codes according to the International Classification of Disease, procedures according to the Nomesco Classification of Surgical Procedures, and date of admission).[16] According to baseline characteristics, hypertension was defined as either a registered diagnosis of hypertension in the National Patient Register before inclusion in the study or use of antihypertensive medication. The source population, recruitment and invitation procedure, data collection, and data processing in the Copenhagen City Heart study are described in detail elsewhere.[14] Participants were excluded from this substudy if (1) no echocardiogram was obtained, (2) the participant had a history of aortic dissection/ruptured aortic aneurysm/aortic aneurysm surgery or a history of heart valve surgery; and/or (3) insufficient image quality not allowing measurement the aortic dimensions or if it was possible to measure only the aortic annular diameter.

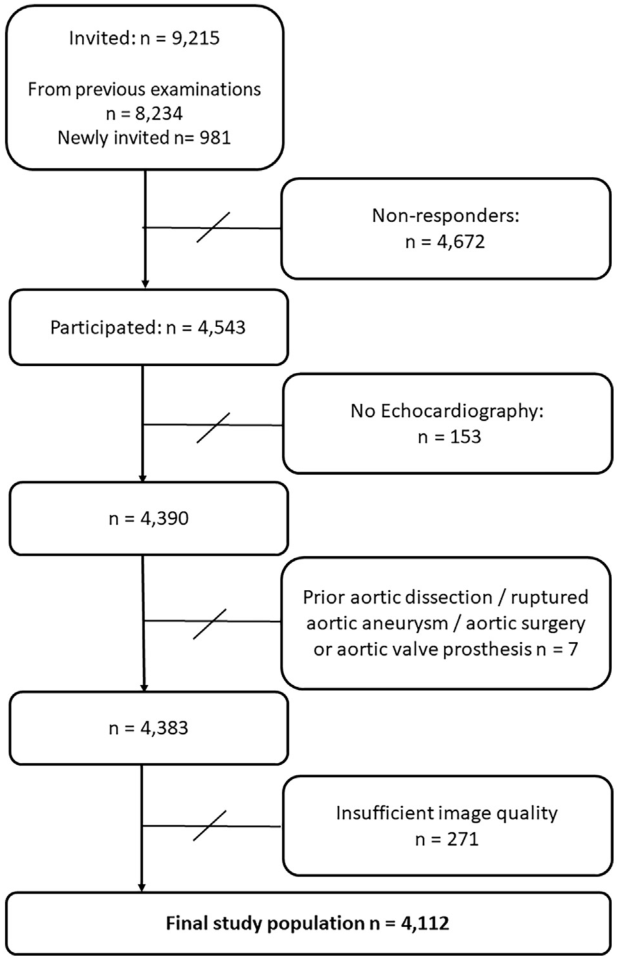


Figure 1. Flow chart of selection of the study participants.

Height was measured without shoes on a fixed scale to the nearest 0.1 cm. Weight was measured with clothes but without shoes on a consultation scale (Seca, Hamburg, Germany) to the nearest 0.1 kg. A total of 3 blood pressure measurements were taken on the participants' nondominant arm using an automatic blood pressure monitor (OMRON M3, OMRON Healthcare, Hoofddorp, the Netherlands) after 5 minutes of rest in a seated position. An average of 3 blood pressure measurements were calculated for each participant.

Participants underwent standardized transthoracic echocardiograms performed with GE Vivid E9 (GE Healthcare, Horten, Norway) ultrasound machines by experienced sonographers. The echocardiograms were stored in a remote archive and analyzed offline by a single experienced blinded investigator using commercially available software (EchoPAC version 201 and 202, GE Healthcare, Little Chalfont, United Kingdom). To evaluate interobserver and intraobserver reliability, blinded duplicate determinations of the aortic dimensions were performed for 50 participants. In the parasternal long-axis view on 2D echocardiography, the following dimensions were measured: (1) aortic annular diameter, measured between the hinge points of aortic leaflets (inner edge-to-inner edge) in systole,[17,18] (2) sinus of Valsalva, (3) sinotubular junction, and (4) tubular part of ascending aorta (as the maximum diameter visualized and minimum 1 cm from the sinotubular junction) using the leading edge-to-leading edge convention in diastole.[19] Diameters were all measured perpendicular to the long axis of the aorta to the nearest 0.1 cm. It was noted if the aortic valve was bicuspid and if aortic regurgitation was present and the aortic valve area was estimated in case of aortic stenosis (≤1.5 $cm^2$).

The participants were followed up until an aortic event (aortic dissection or ruptured aortic aneurysm: International Classification of Disease, Tenth Revision codes DI71.0, DI71.0A, DI71.0B, DI71.1, DI71.3, DI71.5, and DI71.8), death, or end of follow-up on December 13, 2018, whichever came first.

Patient characteristics were summarized by gender with mean and SD or median and range according to sample distribution for continuous variables. Categorical variables were summarized with counts and percentages. Outcome variables were summarized by gender with mean and 95% confidence interval (CI). Linear regression was used to calculate the association between patient characteristics and measured sinus diameter. For each exposure variable, a crude model, gender-adjusted model, and fully adjusted model were presented. The adjustment variables were chosen based on clinical considerations, as listed in Table 3. The results from the linear regression model are presented with 95% CIs. Because of the high collinearity some variables (e.g., pulse pressure and body mass index [BMI]) were not included as adjustment variables. Interclass and intraclass correlation coefficients (ICCs) were calculated for the aortic measurements: aortic annulus diameter, sinus of Valsalva, sinotubular junction, and ascending aorta (tubular part). For the intraobserver and interobserver reliability, a 2-way single measurement, mixed-effect model with absolute agreement was used. The ICCs were interpreted according to Koo et al[20] and presented with 95% CI. Model assumptions were investigated graphically, including linearity, homoscedasticity, independence, and normality of residuals. Finally, the incidence rates for acute aorta events (aortic dissections or ruptured aortic aneurysm) and death were calculated. Missing observations were omitted as part of complete cases analysis. Missing observations are listed in Table 2. A 5% significance level was used for all statistical tests. All analyses were performed in STATA version 17 (StataCorp 2021. Stata Statistical Software: Release 17, StataCorp LLC, College Station, Texas).

The study complied with the Helsinki Declaration and was approved by the National Committee on Health Research Ethics (H-KF 01-144/01 31,104) and the Danish Data Protection Agency (approval no.: 2001-54-0280; 2007-58-0015, 2012-58-0004, HEH-2015-045, I-suite 03741). Written informed consent was obtained from all participants. Study data from postprocessing of the echocardiograms were collected and managed using REDCap electronic data capture tools hosted at Aalborg University Hospital, Denmark.[21,22] REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies, providing (1) an intuitive interface for validated data capture; (2) audit trails for tracking data manipulation and export procedures, (3) automated export procedures for seamless data downloads to common statistical packages, and (4) procedures for data integration and interoperability with external sources.[21−23]

## Results

The study population comprised 4,112 participants from the fifth examination round of the Copenhagen City Heart study without previous acute aortic syndrome, aortic surgery, or heart valve surgery. A flowchart of the study population is listed in Figure 1. Men, with a mean age of 56 ± 17 years (range 21 to 98 years), accounted for 44% of the study population and women, with a mean age of 57 ± 18 years (range 20 to 98 years), for 56% (Table 1). Anthropometric measures, co-morbidity, and smoking status are listed in Table 1. The mean BMI was 26 in male participants and 25 in female participants. A total of 25% of the participants had known hypertension at inclusion, whereas only a small proportion had known ischemic heart disease (3%) and diabetes (6%). A total of 60% of the participants were current or former (the majority) smokers. The mean systolic and diastolic blood pressure was 140/80 mm Hg in male participants and 136/77 mm Hg in female participants.

Aortic root diameters were larger at all 4 levels in men than in women (Table 2). Aortic sinus diameters indexed to height were largest in men, whereas aortic sinus diameters indexed to body surface area tended to be higher in women. However, the difference was not statistically significant ($p = 0.10$). Aortic diameter at sinus of Valsalva by gender and age is depicted in Figures 2 and 3. Among the men, 22.6% had an aortic sinus of ≥4 cm and among the women, 1.6%. A bicuspid aortic valve was found in 1.2% (n = 20/

Table 1
Characteristics of the participants

| Variable | Men (n = 1,796) | Women (n = 2,316) |
|---|---|---|
| Age, years | 56.4 (17.0) | 56.9 (18.1) |
| Height, m | 1.78 (0.07) | 1.65 (0.07) |
| Weight, kg | 84.0 (13.6) | 68.6 (12.8) |
| BMI, $kg/m^2$ | 26.3 (3.9) | 25.2 (4.7) |
| BSA, $m^2$ | 2.02 (0.17) | 1.75 (0.16) |
| Systolic BP, mmHg | 140.3 (18.5) | 135.8 (22.2) |
| Diastolic BP, mmHg | 80.4 (10.8) | 77.3 (10.6) |
| Mean arterial pressure, mmHg | 100.4 (12.1) | 96.8 (12.9) |
| Pulse pressure, mmHg | 59.8 (14.5%) | 58.5 (18.0%) |
| Hypertension | 466 (25.9%) | 554 (23.9%) |
| Diabetes | 126 (7.0%) | 102 (4.4%) |
| Ischemic heart disease | 88 (4.9%) | 29 (1.3%) |
| Hypercholesterolemia | 104 (5.8%) | 95 (4.1%) |
| Smoking status | | |
| Current | 357 (20.2%) | 386 (17.1%) |
| Former | 744 (42.2%) | 932 (41.2%) |
| Never | 662 (37.5%) | 944 (41.7%) |

BMI = body mass index; BP = blood pressure; BSA = body surface area.
Continuous variables are presented as means (SD) and categorial variables as numbers (%).

Table 2
Echocardiographic characteristics of the participants

| Variable | Men (n = 1,796) | Women (n = 2,316) | Missing |
|---|---|---|---|
| Aortic annulus, cm | 2.2 [2.2;2.3] | 2.0 [2.0;2.0] | 114 (2.8) |
| Aortic sinus, cm | 3.7 [3.7;3.7] | 3.2 [3.2;3.2] | 63 (1.5) |
| Sinotubular junction, cm | 3.1 [3.1;3.1] | 2.7 [2.7;2.8] | 469 (11.4) |
| Ascending aorta (tubular part), cm | 3.2 [3.2;3.2] | 2.9 [2.8;2.9] | 1,076 (26.2) |
| Aortic sinus/height, cm/m | 2.1 [2.1;2.1] | 2.0 [1.9;2.0] | 63 (1.5) |
| Aortic sinus/ BSA, cm/m$^2$ | 1.8 [1.8;1.9] | 1.9 [1.8;1.9] | 67 (1.6) |

BSA = body surface area.
Continuous variables are presented as means [95% CI].

1,696) of male participants and 0.4% (n = 8/2,267) in female participants. The corresponding figures for aortic stenosis were 3.6% in men and 2.2% in women, with a mean estimated aortic valve area of 1.2 (range 0.5 to 1.5 cm$^2$). Aortic valve regurgitation was present in 13% of the participants, predominantly very mild valve disease. The aortic root diameters in the participants with a bicuspid aortic valve were larger at all 4 levels—annulus: 2.2 (95% CI 2.1 to 2.3) vs 2.1 (2.1 to 2.1) cm, sinus of Valsalva: 3.8 (3.6 to 4.0) vs 3.4 (3.4 to 3.4) cm, sinotubular junction: 3.2 (3.0 to 3.4) vs 2.9 (2.9 to 2.9) cm, and ascending aorta: 3.4 (3.2 to 3.6) vs 3.0 (3.0 to 3.0) cm.

Beyond the correlation with gender, the crude and gender-adjusted analyses showed a significant positive correlation of the aortic sinus diameter with age, height, weight, systolic blood pressure, diastolic blood pressure, mean arterial pressure, pulse pressure, hypertension, diabetes, ischemic heart disease, and smoking (Table 3). However, in the fully adjusted model, only age, height, weight, and diastolic blood pressure remained significantly positively correlated with aortic sinus diameter. For systolic blood pressure and pulse pressure, the correlation was inverse in the fully adjusted model, despite remaining statistically significant (Table 3).

The median follow-up was 5.4 (quartile 1 to quartile 3 4.5 to 6.3) years. During follow-up, there were 3 registered cases of first-time aortic dissection or ruptured thoracic aortic aneurysm in the study population, corresponding to an incidence rate of 13.6 (95% CI 4.4 to 42.2) per 100,000

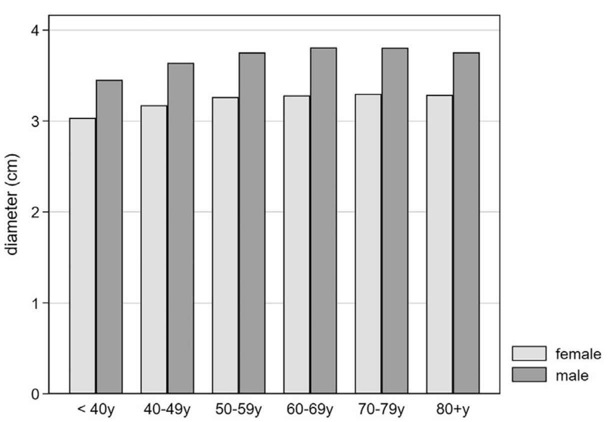


Figure 2. Diameter of sinus of Valsalva by age and gender.

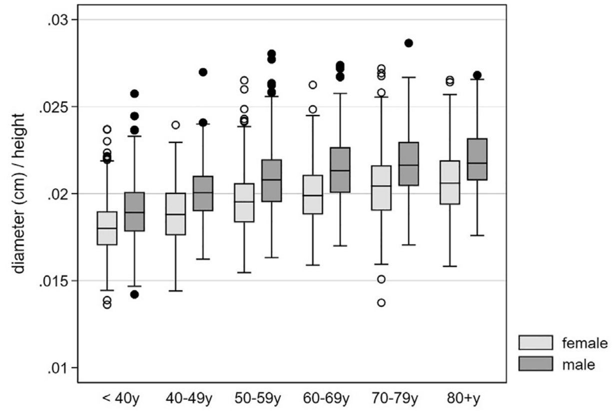


Figure 3. Box plot of height-indexed diameter of sinus of Valsalva by age and gender.

person-years. A total of 248 participants died during follow-up, corresponding to an annual death rate of 1.1% (95% CI 1.0 to 1.3).

The annular aortic diameter was assessable in 97.2% of the study population and the aortic sinus diameter in 98.5%. The corresponding number for the sinotubular junction was 88.6% and for the tubular part of the ascending aorta, 73.8%. The intraobserver reliability and interobserver reliability for all 4 levels are depicted in Bland−Altman plots (Figures 4 and 5). The intraobserver reproducibility was high for all variables, with ICCs ranging from 0.82 to 0.96. The interobserver reproducibility was similar (ICC 0.79 to 0.88). The ICC was highest for the aortic sinus.

## Discussion

This study presents standardized aortic root measurements derived from the population-based Copenhagen City Heart study cohort with state-of-the-art transthoracic echocardiography in 4,112 adults. Beyond male gender and age, only height, weight, and diastolic blood pressure remained significantly positively correlated with aortic sinus diameter after full adjustment. For systolic blood pressure and pulse pressure, the correlation was inverse. The aortic root was larger at all 4 levels in participants with a bicuspid aortic valve. During follow-up, the incidence rate of first-time aortic dissection or ruptured aortic aneurysm was 13.6 (CI 4.4 to 42.2) per 100,000 person-years.

The aortic sinus is a geometrically complex structure that stores pulsatile stress from ventricular contraction during systole and delivers the energy during diastole through the "windkessel" effect.[24] The aortic diameter changes slightly during systole and diastole.[25,26]

In this study, the mean aortic diameters were almost identical with the measurements reported in a recently published study from Germany, with a comparable population-based cohort.[26] In this study, the diameters at the sinotubular junction and at the ascending aorta were slightly larger, which may be explained by the leading edge-to-leading edge technique used here, as opposed to inner edge-to-inner edge technique, which is used in the Hamburg City Health Study[26] at these 2 levels as indicated by the EACVI NORRE study in which aortic root values were measured

Table 3
Associations between clinical characteristics and sinus of Valsalva diameter

| Variable | Crude β (CI)‡‡ | P | Sex adjusted β (CI) ‡‡ | P | Fully adjusted model β (CI)‡‡ | P |
|---|---|---|---|---|---|---|
| Age | 0.006 (0.005;0.007) | <0.001 | 0.006 (0.006;0.007) | <0.001 | - | - |
| Height (m) | 0.019 (0.017;0.020) | <0.001 | 0.003 (0.002;0.005) | <0.001 | 0.012 (0.010; 0.013) * | <0.001 |
| Weight (kg) | 0.012 (0.012;0.013) | <0.001 | 0.006 (0.005;0.007) | <0.001 | 0.004 (0.003;0.005) † | <0.001 |
| BMI (kg/m$^2$) | 0.022 (0.020;0.025) | <0.001 | 0.016 (0.013;0.018) | <0.001 | 0.010 (0.008;0.012) ‡ | <0.001 |
| BSA (m$^2$) | 0.997 (0.945;1.045) | <0.001 | 0.460 (0.399;0.522) | <0.001 | 0.553 (0.475;0.592) ‡ | <0.001 |
| SBP (mmHg) | 0.003 (0.003;0.004) | <0.001 | 0.002 (0.002;0.003) | <0.001 | -0.001 (-0.002;-0.001)§ | <0.001 |
| DBP (mmHg) | 0.008 (0.007;0.010) | <0.001 | 0.005 (0.005;0.006) | <0.001 | 0.003 (0.002;0.004) § | <0.001 |
| MAP (mmHg) | 0.007 (0.006;0.008) | <0.001 | 0.005 (0.004;0.005) | <0.001 | 0.001(-0.000;0.002) § | 0.093 |
| PP (mmHg) | 0.002 (0.001;0.002) | <0.001 | 0.001 (0.000;0.002) | 0.001 | - 0.003 (-0.004;-0.003) § | <0.001 |
| Hypertension | 0.136 (0.107;0.165) | <0.001 | 0.127 (0.104;0.150) | <0.001 | 0.014 (-0.011;0.039) ¶ | 0.276 |
| Diabetes | 0.126 (0.070,0.181) | <0.001 | 0.070 (0.025;0.115) | 0.002 | -0.031 (-0.073;0.012) ** | 0.162 |
| IHD | 0.248 (0.173;0.324) | <0.001 | 0.094 (0.032;0.156) | 0.003 | -0.014 (-0.072;0.044) †† | 0.630 |
| Smoking (ever) | 0.065 (0.039;0.091) | <0.001 | 0.046 (0.025;0.067) | <0.001 | 0.007 (-0.013;0.027) * | 0.482 |

BMI = body mass index; BSA = body surface area; DBP = diastolic blood pressure; IHD = ischemic heart disease; MAP = mean arterial blood pressure; PP = pulse pressure; SBP = systolic blood pressure.

* Adjusted for sex and age.

† Adjusted for sex, age height, diabetes, and smoking.

‡ Adjusted for sex, age, diabetes, and smoking.

§ Adjusted for sex, age, BSA, hypertension, diabetes, IHD, and smoking.

¶ Adjusted for sex, age, BSA, diabetes, IHD and smoking, SBP, and DBP.

** Adjusted for sex, age, BSA, hypertension, IHD, smoking.

†† Adjusted for sex, age, BSA, hypertension, diabetes, smoking.

‡‡ How much one unit change in relevant variable affect the sinus diameter (measured in cm).

using the leading edge-to-leading edge technique and inner edge-to-inner edge technique in the subjects.[25] This comparability supports the reliability of transthoracic echocardiography to the measure aortic root dimension, as also indicated by high interclass and intraclass correlations in this study.

The early population-based studies on aortic root dimensions used M-mode.[8] However, M-mode has been superseded and replaced by the 2D technique in all studies from the past decades.[11,25,26] We followed the recent American Society of Echocardiography/ European Association of Cardiovascular Imaging guidelines, using the inner edge-to-inner edge technique in systole for aortic annulus and the leading edge-to-leading edge technique in diastole for sinus of Valsalva, sinotubular junction, and tubular part of the ascending aortic.[19,27]

As previously shown, we found that aortic diameters increased with age.[8,25,26] With aging, vessel compliance decreases and wall stiffness increases because of a decrease in elastin content of vessel walls and increased collagen content.[28] The aortic sinus diameter increase also correlates with calcification and atherosclerosis.[29] With age and aortic stiffness, systolic blood pressure and pulse pressure increase.[30] Systolic hypertension is closely associated with

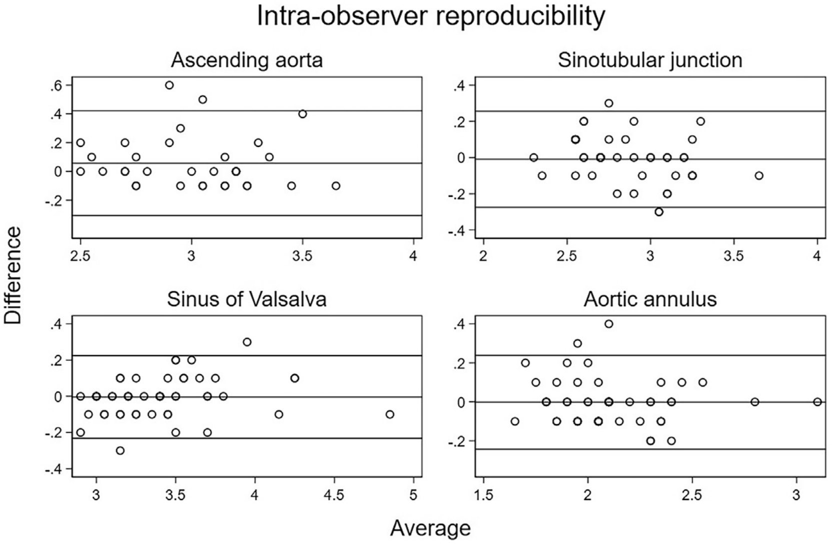


Figure 4. Bland−Altman plot for intraobserver reproducibility.

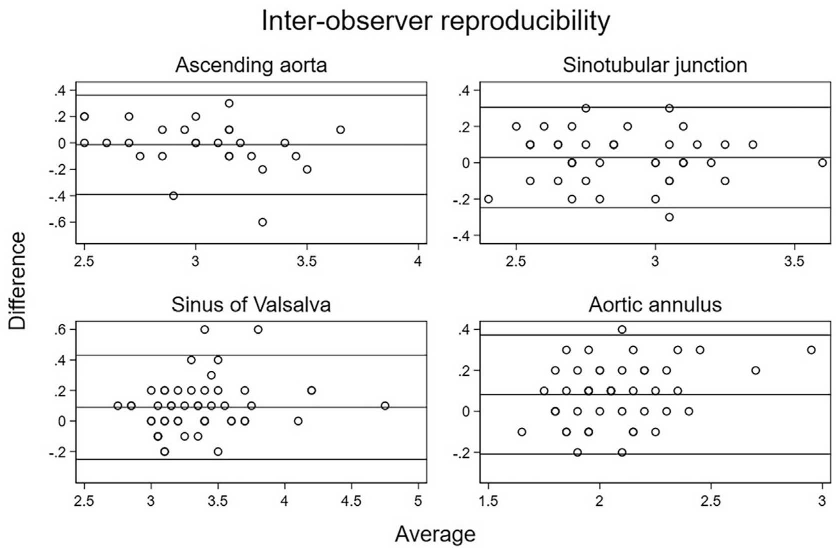


Figure 5. Bland−Altman plot for interobserver reproducibility.

cardiovascular events, whereas diastolic blood pressure does not seem to have the same major impact on the cardiovascular event rate.[31,32]

This is enigmatic because we found a significant correlation between aortic size and diastolic blood pressure. However, this has also been shown in other population-based studies such as the Framingham study, Strong Heart study, Campania Salute Network that included patients with hypertension, and HyperGen study that comprised a mixed population with patients with normotension and hypertension.[8,11,12,33] The diastolic pressure is the vessel pressure when the aortic valve is closed and the pressure to overcome by left ventricular contraction during systole. The association between diastolic blood pressure and aortic size is not well explained. Many theories have been tested, particularly, that small aortic diameters generate systolic hypertension, which will bias the interpretation of cross-sectional observations.[34] However, longitudinal observational data have not supported this theory.[34] Another reason could also be the relation between diastolic blood pressure and obesity, sedentary lifestyle issues, smoking, and alcohol intake. The correlation between anthropometric measures, such as BMI, and aortic dilatation and that overweight and diastolic blood pressure are related to the aortic diameter suggest that there could be a close link between lifestyle issues and diastolic hypertension that may be challenging to disentangle, even with advanced statistical methods. Obesity demonstrated significant association with aortic diameter in the HyperGen study, Jackson Heart study, and Strong Heart study.[11,33,35] Lifestyle changes could potentially hold the key to maintaining a normal aortic diameter.[11,33,35] This was addressed in a small study by Stoll et al,[36] where weight loss was associated with significant reductions in blood pressure and the diameter of the descending aorta.

The participants in the present study were followed up for a median of 5.4 years after inclusion. During follow-up, the incidence rate of registered first-time aortic dissection or ruptured aortic aneurysm was 13.6/100,000/year. This number cannot be directly compared with previous findings. However, in the population-based OXVASC study, where participants were included irrespective of age and where also out-of-hospital deaths and autopsy data were included, the investigators found an incidence of aortic dissection at 6/100,000/year and an incidence of ruptured/symptomatic aortic aneurysm of 11/100,000/year.[10] A recent registry-based study, which also included out-of-hospital deaths, described a higher annual incidence of acute aortic dissection than previous reports (7.2/100,000).[37] The recent KP-TAA study found a need for prophylactic aortic surgery in 5% over approximately 4 years in cases with an aortic size below 4 cm at inclusion and they reported no dissections.[38] This leaves the question whether it is cost beneficial to conduct population-based screening of aortic root diameters to prevent aortic dissection and death because of aortic disease. This was not the case in the DANCAVAS study where over 10,000 men were screened, intervened on if needed, and followed up for 5.6 years.[39] At the end of the study, no difference in the number of aortic events between the screened participants and the control group was seen.[39] These findings question the value of prioritizing assessment of aortic dimensions in a population-based setting. A recently published echocardiographic study found minimal change in dimensions over 10 years in patients with mild to moderate degenerative thoracic aortic aneurysm (<4.5 cm) without hereditary or genetic predispositions and suggest that the guidelines for follow-up should be more liberal.[40]

This study had some limitations. First and foremost, this population comes from a region in Europe with relatively high living standards and is characterized by good health, evidenced by lower BMI and a low prevalence of comorbidities. The BMI levels align with those found in the Hamburg City Health study but are notably lower than the cohorts of the Strong Heart, HyperGen, and the Jackson Heart studies.[11,26,33,35] Despite the comparable mean age to most population studies, exceptions are noted in the EACVI NORRE and Strong Heart studies.[11,25] It is crucial to factor in these considerations when interpreting the results. Moreover, some participants (<1%) were excluded from the study because of insufficient image quality of the echocardiograms. Furthermore, in the final study population, the diameter was not assessable at the sinotubular junction in more than 10% and at the tubular part of the ascending aorta in more than 25%. In contrast, the diameters at the aortic annulus and the sinus of Valsalva were assessable in close to 100%. However, the present cohort is large. Hence, the presented mean diameters at all 4 levels are based on a very large number of patients. Finally, we only had 1 echocardiogram per participant and a relatively short follow-up period. It would have been valuable to have follow-up data on aortic root size after some years allowing us to analyze growth and factors associated with growth and aortic dissection.

In conclusion, beyond anthropometric measures, age, and male gender, diastolic blood pressure was the only cardiac risk factor that was independently and positively correlated with aortic root dimensions. Systolic blood pressure and pulse pressure were inversely correlated. The number of events with either aortic dissection or death because of aortic disease was low.

### Declaration of competing interest

Dr. Biering-Sørensen is a steering committee member of the Amgen-financed GALACTIC-HF trial, the Boehringer Ingelheim-financed EASi-KIDNEY trial, and “LUX-Dx TRENDS Evaluates Diagnostics Sensors in Heart Failure Patients Receiving Boston Scientific’s Investigational ICM System” trial: chief investigator of the Sanofi Pasteur-financed “NUDGE-FLU” trial, the Sanofi Pasteur-financed “DANFLU-1” trial, and the Sanofi Pasteur-financed “DANFLU-2” trial; is on the advisory board for Sanofi Pasteur, Amgen, CSL Seqirus, and GSK; received speaker honoraria from Bayer, Novartis, Sanofi Pasteur, GE Healthcare, and GSK; received research grants from GE Healthcare, AstraZeneca, Novo Nordisk, and Sanofi Pasteur; and is a consultant for Novo Nordisk, IQVIA, and Parexel. The remaining authors have no competing interest to declare.

### CRediT authorship contribution statement

**Kirsten Duch:** Formal analysis, Visualization, Writing − review & editing. **Bhupendar Tayal:** Writing − review & editing. **Andreas Hagendorff:** Writing − review & editing. **Tor Biering-Sørensen:** Writing − review & editing. **Peter Schnohr:** Writing − review & editing. **Rasmus Møgelvang:** Writing − review & editing. **Nis Høst:** Writing − review & editing. **Kristian Kragholm:** Conceptualization, Methodology, Supervision, Writing − review & editing. **Peter Søgaard:** Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Writing − review & editing.


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