# Aortoiliac Diameter and Length in a Healthy Cohort

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## Abstract

Objective: Diameter is currently the only screening and diagnostic criterion for asymptomatic aneurysms. Therefore, aortic and lower-extremity arterial diameter has diagnostic, therapeutic, and prognostic importance. We aimed to determine aortic and lower-extremity arterial reference diameters in a general population and compare them according to age, sex, and other characteristics.

Methods: We evaluated consecutive 3,692 patients who underwent computed tomography as part of a general health checkup from 2015–2019 in a single tertiary center. Aortic and lower-extremity arterial diameters and the most important factor related to arterial diameters were evaluated.

Results: The mean diameter of the abdominal aorta was 17.490 ± 2.110 mm, while that of the common iliac artery was 10.851 ± 1.689 mm. The mean diameter of the abdominal aorta was 18.377 ± 1.766 mm in men and 15.884 ± 1.694 mm in women. Significant intersex differences were observed for all mean diameters and lengths. Multilinear regression analysis showed that age, sex, and body surface area impacted mean diameters of all measured sites except aorta and common iliac artery length. Between male and female patients matched for body surface area, there were significant intersex differences for all measured sites, except for common iliac artery length.

Conclusions: The mean diameter of the abdominal aorta in this healthy cohort was 17.490 ± 2.110 mm overall, 18.377 ± 1.766 mm in men, and 15.884 ± 1.694 mm in women. Arterial diameter increased with male sex, older age, and increased body surface area, and aortic diameters were larger in men than in women with the same body surface area.

## Introduction

Currently, diameter is the only screening and diagnostic criterion for asymptomatic aneurysms. Abdominal aortic aneurysm (AAA) is defined as a 50% or greater increase in infrarenal aortic diameter (IAD) or infrarenal aorta with a maximum diameter ≥ 3.0 cm.[1–3] Aneurysm size is one of the strongest predictors for risk of rupture, with a markedly increased risk when aneurysm diameters are greater than 5.5 cm.[4,5] Therefore, aortoiliac arterial diameter has diagnostic, therapeutic and prognostic importance.

Women have up to a four-fold higher risk of AAA rupture than men at any given aneurysm diameter.[6] The Joint Council of the American Association of Vascular Surgery and the Society for Vascular Surgery have suggested a lower diameter threshold for AAA repair in women.[7] One hypothesis is that because women generally have a smaller body and vascular size than men, an aneurysm of a certain size in a woman represents a greater relative dilatation of the aorta compared with the same aneurysm in a man.[8] In order to apply the concept of relative expansion according to sex or body size, the reference diameter is of clinical importance. There are published reference ranges for the aorta and the lower-extremity vessels using ultrasound or contrast-enhanced computed tomography (CT) [9–11]. However, there are few papers on Asian populations, the body sizes of whom are relatively small compared to Westerners. Considering its clinical importance and lack of sufficient data, we purposed to measure aortoiliac and lower-extremity arterial reference diameters in an Asian healthy population. In addition, we determined whether body size was a significant factor for aortoiliac diameter and whether there was an intersexual difference in the diameter when body size was similar.

# Methods

We retrospectively evaluated patients who underwent CT for general health checkup from 2015 to 2019. This study was approved by Asan Medical Center Institutional Review Board (No. 2016 – 0232) and waived the need for informed consent because of the retrospective nature of the study and the lack of information on the participant's identification. This study complies with the Declaration of Helsinki.

All imaging examinations were performed using a multi-slice CT scanner (Lightspeed VCT; GE Healthcare, IL, US). Parameters for the acquisitions were 5-mm slice thickness, 120 KVp, and 215–360 mA tube current. Imaging was initiated after the administration of low osmolar iodinated contrast agent (Iopamiro 2 mL/kg; iodine concentration, 320 mg/mL). Soft-tissue window settings with a width of 300 HU and a center of 50 HU were applied. This sizing was performed using Endosize (Therenva, Rennes, France), a 3D sizing software tool that measures diameters perpendicular to the long axis of the arteries. Lengths and diameters taken on the vessel centerlines were automatically obtained after a simple interactive step consisting of a 3D point picking sequence. The measured site is depicted in Fig. 1. Aortic diameter was measured just below the superior mesenteric artery (SMA), lowest renal artery, and at the bifurcation. Mean aortic diameter from three sites was used in the regression analysis. Aortic length was measured between the lowest renal artery and the bifurcation. The diameter of the common iliac artery (CIA) was measured at the midpoint between the aortic and iliac bifurcation and at the broadest point, and the external iliac artery (EIA) diameter was measured at the iliac bifurcation on the arterial centerline. CIA length was measured between the aortic bifurcation and the iliac bifurcation on the centerline. Iliac artery length was measured between the aortic bifurcation and the femoral bifurcation. Common femoral artery diameter was measured at the femoral bifurcation level. Measurements using Endosize were made by four vascular surgeons. Measurement sites are depicted in Fig. 1. To test the reliability, all four of the examiners randomly measured the data of the selected 106 patients using a random number generation function in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Clinical information was obtained from the questionnaires and measurements from the general health checkup database, including height, weight, history of smoking, hypertension, and diabetes. History of smoking was defined as current or former smokers based on patient-provided information. Body mass index (BMI) was calculated by dividing the weight in kilograms by the square of the height in meters. Body surface area (BSA) was calculated using the Mosteller formula.[12] Diabetes was defined as fasting plasma glucose (FPG) levels $\geq$ 7.0 mmol/L or glycated hemoglobin (HbA1c) levels $\geq$ 6.5 %. In addition, individuals taking anti-diabetic medication were considered to have diabetes. Hypertension was defined as systolic and/or diastolic blood pressure $\geq$ 140/90 mmHg and/or taking antihypertensive medication.

Quantitative and qualitative variables were summarized separately by descriptive statistics. For quantitative variables, an independent sample t-test or one-sample t-test was used to assess differences in the diameters. Correlation was assessed using the intraclass coefficient correlation (ICC), and complete agreement was defined as 1.0. A generalized linear model with stepwise selection was fit to assess the associations between baseline characteristics and the diameters of the lower extremities after normality testing (Kolmogorov-Smirnov test, Cramer-von Mises, and Anderson-Darling). Men and women with the same BSA were extracted using R software version 4.0.2 (R Development Core Team, 2006). Where multiple patients were present for one BSA value, the mean values of each sex were used as representative values. Comparison of aortic diameters was performed between matched men and women using paired t-tests. Our data were compared with those of previous studies on aortic diameters using one-sample t-test. p values < 0.05 were considered significant. The statistical analysis was performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA) and SPSS version 23.0 software (Armonk, NY, USA).

# Results

A total of 3,692 subjects (35.6% female) were included in the analysis. Baseline characteristics are summarized in Table 1. Mean age was 57.3 ± 8.7 years (range, 21–88 years) (median age, 57 years; 5% trimmed mean, 57.2 years). All ICC were above 0.9 except for aortic diameter at the bifurcation: aortic diameter at the SMA level, 97.3% [96.3%, 98.0%] ($P < .001$); aortic diameter at the lowest renal artery level, 93.9% [91.7%, 95.6%] ($P < .001$); aortic diameter at the bifurcation, 78.1% [69.7%, 84.4%] ($P = .003$); right CIA diameter, 91.1% [87.7%, 93.7%] ($P < .001$); left CIA diameter, 95.6% [93.9%, 96.9%] ($P < .001$); aortic length, 96.2% [94.9%, 96.3%] ($P < .001$); right CIA length, 97.8% [97.0, 98.4%] ($P < .001$); and left CIA length, 97.4% [96.4%, 98.1%] ( $P < .001$).

Table 1
Patients' Demographic Data

| | Total | | Male | Female | P |
|---|---|---|---|---|---|
| Number | 3,692 | | 2,379 (64.4%) | 1,313 (35.6%) | |
| Age | 57.3 ± 8.7 (range, 21–88) | | 56.8 ± 8.7 | 58.1 ± 8.6 | < 0.001 |
| Height | 166.3 ± 8.4 (range, 137.4-191.7) | | 170.9 ± 5.8 | 157.8 ± 5.4 | < 0.001 |
| BMI | 24.33 ± 3.05 (range, 15.13–45.27) | | 25.0 ± 2.8 | 23.2 ± 3.06 | < 0.001 |
| BSA | 1.76 ± 0.19 (range, 1.19–2.77) | | 1.86 ± 0.15 | 1.59 ± 0.11 | < 0.001 |
| Hypertension | 1,106 (30%) | | 795 (33.4%) | 344 (23.7%) | < 0.001 |
| DM | 547 (14.8%) | | 434 (18.2%) | 113 (8.6%) | < 0.001 |
| Smoking | Nonsmoker | 1,689 (45.7%) | 462 (19.4%) | 1,227 (93.8%) | < 0.001 |
| | Current smoker | 749 (20.3%) | 713 (30.0%) | 36 (2.8%) | |
| | Ex-smoker | 1,247 (33.8%) | 1,202 (50.6%) | 45 (3.4%) | |
| CVD | 1,633 (44.2%) | | 1,187 (49.9%) | 446 (34.0%) | < 0.001 |
| BUN | 13.12 ± 3.54 (range, 3–30) | | 13.5 ± 3.4 | 12.4 ± 3.6 | < 0.001 |
| Creatinine | 0.85 ± 0.17 (range, 0.4–1.44) | | 0.93 ± 0.1 | 0.69 ± 0.1 | < 0.001 |
| eGFR | 90.81 ± 11.96 (range, 50–127) | | 89.5 ± 12.0 | 93.2 ± 11.5 | < 0.001 |
| HbA1c | 5.78 ± 0.81 (range, 4.0-13.2) | | 5.8 ± 0.9 | 5.7 ± 0.7 | < 0.001 |
| Cholesterol | 185.62 ± 40.15 (range, 78–385) | | 181.6 ± 40.4 | 192.5 ± 38.7 | < 0.001 |
| Triglyceride | 123.54 ± 84.93 (range, 13-1190) | | 136.8 ± 94.1 | 99.5 ± 57.9 | < 0.001 |
| HDL | 55.75 ± 16.02 (range, 19–185) | | 51.9 ± 14.0 | 62.7 ± 17.0 | < 0.001 |
| LDL | 127.29 ± 37.39 (range, 32–316) | | 125.5 ± 37.9 | 130.5 ± 36.2 | < 0.001 |

BMI, body mass index; BSA, body surface area; BUN, blood urea nitrogen; CVD, any type of cardiovascular disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol

# Mean diameters and lengths

Mean diameters and lengths are shown in Table 2. The mean diameter of the abdominal aorta was 17.490 ± 2.110 mm, while that of the CIA was 10.851 ± 1.689 mm. No patients had an aortic diameter ≥ 3 cm. The mean diameter of the aorta was 18.377 ± 1.766 mm in men and 15.884 ± 1.694 mm in women (Fig. 2). The mean diameter of the CIA was 11.436 ± 1.512 mm in men and 9.793 ± 1.464 mm in women.

For all mean diameters and lengths, significant differences between men and women were observed (all p values were less than 0.001, except for both CIA lengths [$P = .048$ for right side, $P = .034$ for left side]).

Table 2
Arterial Diameters and Lengths

| Location | Overall<br>Mean (mm) ± SD | Interquartile range | Men<br>Mean (mm) ± SD | Women<br>Mean (mm) ± SD |
|---|---|---|---|---|
| Aorta, SMA level | 19.116 ± 2.490 | 17.4–20.7 | 20.080 ± 2.125 | 17.368 ± 2.123 |
| Aorta, lowest. renal (D) | 17.014 ± 2.301 | 15.5–18.6 | 17.867 ± 2.041 | 15.469 ± 1.909 |
| Aorta, bifurcation (D) | 16.340 ± 2.240 | 14.8–17.6 | 17.183 ± 2.012 | 14.814 ± 1.783 |
| Mean aorta (D) | 17.490 ± 2.110 | 16.07–18.90 | 18.377 ± 1.766 | 15.884 ± 1.694 |
| Mean aorta (L) | 92.977 ± 13.436 | 30.0-145.0 | 94.271 ± 13.620 | 90.620 ± 12.750 |
| Rt. CIA, max (D) | 11.376 ± 2.028 | 10.0-12.6 | 11.970 ± 1.898 | 10.303 ± 1.800 |
| Lt. CIA, max (D) | 11.175 ± 1.994 | 9.8–12.4 | 11.784 ± 1.855 | 10.073 ± 1.751 |
| Rt. CIA, mid (D) | 10.494 ± 1.851 | 9.2–12.4 | 11.065 ± 1.714 | 9.460 ± 1.628 |
| Lt. CIA, mid (D) | 10.359 ± 1.812 | 9.1–11.5 | 10.924 ± 1.684 | 9.334 ± 1.572 |
| Mean CIA (D) | 10.851 ± 1.689 | 9.7–11.9 | 11.436 ± 1.512 | 9.793 ± 1.464 |
| Rt. CIA (L) | 48.656 ± 15.170 | 9.0-106.0 | 49.029 ± 15.174 | 47.994 ± 15.151 |
| Lt. CIA (L) | 53.493 ± 16.257 | 4.0-121.0 | 53.926 ± 16.286 | 52.726 ± 16.173 |
| Mean CIA (L) | 51.075 ± 14.407 | 41.5–60.0 | 51.478 ± 14.470 | 50.360 ± 14.269 |
| Rt. CFA (D) | 9.015 ± 1.379 | 8.1–9.9 | 9.529 ± 1.220 | 8.085 ± 1.143 |
| Lt. CFA (D) | 9.018 ± 1.426 | 8.1–10.0 | 9.529 ± 1.220 | 8.085 ± 1.143 |
| Mean CFA (D) | 9.017 ± 1.340 | 8.1–9.9 | 9.529 ± 1.170 | 8.091 ± 1.111 |
| Bifurcation, Rt. SFA (L) | 211.455 ± 19.427 | 120.0-306.0 | 215.805 ± 19.082 | 203.598 ± 17.462 |
| Bifurcation, Lt. SFA (L) | 207.891 ± 19.483 | 109.0-283.0 | 212.575 ± 18.778 | 199.431 ± 17.789 |
| Mean Iliac artery (L) | 209.673 ± 18.319 | 196.5-221.5 | 10.800 ± 1.307 | 9.225 ± 1.269 |

CFA, common femoral artery; CIA, common iliac artery; COR, coronal plane; (D), diameter; IQR, interquartile range; (L), length; Lt., left; Rt., right; SFA, superior mesenteric artery; SMA, superior mesenteric artery

| Location | Overall<br>Mean (mm) ± SD | Interquartile range | Men<br>Mean (mm) ± SD | Women<br>Mean (mm) ± SD |
|---|---|---|---|---|
| Bifurcation Rt. SFA in COR (L) | 188.007 ± 17.085 | 176.7-198.5 | 190.505 ± 17.068 | 183.500 ± 16.164 |
| Bifurcation Lt. SFA in COR (L) | 185.193 ± 17.300 | 173.8-197.1 | 188.123 ± 16.750 | 179.881 ± 17.013 |
| CFA, common femoral artery; CIA, common iliac artery; COR, coronal plane; (D), diameter; IQR, interquartile range; (L), length; Lt., left; Rt., right; SFA, superior mesenteric artery; SMA, superior mesenteric artery | | | | |

# Factors affecting diameters and lengths

The linear and multilinear regression analyses for each variable were performed for each diameter and length (Tables 3 and Table 4). The results of multilinear regression showed that age, sex, and BSA were related to the mean diameters and lengths of all measured sites except for CIA length. In the linear regression model, BSA was most explanatory for diameters with the highest $R^2$ values; 0.249 for the infrarenal aorta, 0.277 for the lower abdominal aorta near the bifurcation, 0.217 for the CIA, and 0.254 for the iliac artery. The female sex variable further exhibited high $R^2$ values; 0.249 for the infrarenal aorta, 0.256 for the lower abdominal aorta near the bifurcation, 0.257 for the CIA, and 0.296 for the iliac artery. Results of the multilinear regression analysis with significant variables in the linear regression analysis showed that age, sex, and BSA were related to mean diameters of all measured sites. The $R^2$ value of the reduced model regarding only age, sex, and BSA was not significantly different from that of the full model including all possible variables that were significant in the linear regression; $F_{(3,3687)} = 735.859$, $P < .001$, $R^2 = 0.375$ vs $F_{(6,3684)} = 372.696$, $P < .001$, $R^2 = 0.378$ for the infrarenal aorta, $F_{(3,3687)} = 694.286$, $P < .001$, $R^2 = 0.361$ vs $F_{(6,3684)} = 354.514$, $P < .001$, $R^2 = 0.366$ for the lower abdominal aorta, $F_{(3,3687)} = 640.117$, $P < .001$, $R^2 = 0.345$ vs $F_{(6,3684)} = 326.196$, $P < .001$, $R^2 = 0.347$ for the CIA, $F_{(3,3687)} = 735.448$, $P < .001$, $R^2 = 0.374$ vs $F_{(5,3685)} = 451.133$, $P < .001$, $R^2 = 0.380$ for the iliac artery.

Table 3
Linear and Multilinear Regression of Aortic Diameter and Length with Variables

| | | Linear Regression | | | Multilinear Regression | |
|---|---|---|---|---|---|---|
| | **Variable** | **Coeff.** | $R^2$ | **P** | **Coeff.** | **P** |
| Infrarenal aorta diameter | Female sex | -2.399 | 0.249 | < .0001 | -1.008 | < .0001 |
| | Age | 0.048 | 0.033 | < .0001 | 0.080 | < .0001 |
| | Height* | 0.120 | 0.194 | < .0001 | | |
| | Weight* | 0.093 | 0.229 | < .0001 | | |
| | Body mass index* | 0.246 | 0.105 | < .0001 | | |
| | Body surface area | 6.077 | 0.249 | < .0001 | 5.050 | < .0001 |
| | Current smoker | 0.854 | 0.022 | < .0001 | 0.340 | 0.002 |
| | Ex-smoker | 1.295 | 0.071 | < .0001 | | 0.237 |
| | Hypertension | 0.770 | 0.024 | < .0001 | | 0.155 |
| | DM | 0.484 | 0.006 | < .0001 | -0.173 | 0.044 |
| | HbA1c | 0.237 | 0.007 | < .0001 | | 0.665 |
| | Cholesterol | -0.007 | 0.015 | < .0001 | | 0.667 |
| | Triglyceride | 0.002 | 0.008 | < .0001 | 0.001 | 0.003 |
| Lower abdominal aorta diameter | Female sex | -2.369 | 0.256 | < .0001 | -1.062 | < .0001 |
| | Age | 0.027 | 0.011 | < .0001 | 0.056 | < .0001 |
| | Height* | 0.123 | 0.215 | < .0001 | | |
| | Weight* | 0.096 | 0.257 | < .0001 | | |
| | Body mass index* | 0.254 | 0.117 | < .0001 | | |
| | Body surface area | 6.249 | 0.277 | < .0001 | 5.137 | < .0001 |
| | Current smoker | 0.798 | 0.021 | < .0001 | | 0.146 |
| | Ex-smoker | 1.296 | 0.075 | < .0001 | | 0.909 |
| | Hypertension | 0.721 | 0.022 | < .0001 | | 0.127 |
| | DM | 0.457 | 0.005 | < .0001 | | 0.883 |

Coeff., regression coefficient; HbA1c, glycated hemoglobin

*Height, Weight and Body mass index was not used for the multilinear analysis due to multicollinearity

| | | Linear Regression | | | Multilinear Regression | |
|---|---|---|---|---|---|---|
| | HbA1c | 0.138 | 0.002 | 0.002 | -0.132 | < .0001 |
| | Cholesterol | -0.008 | 0.020 | < .0001 | -0.002 | 0.003 |
| | Triglyceride | 0.002 | 0.009 | < .0001 | -0.001 | 0.030 |
| Aortic Length | Female sex | -3.670 | 0.017 | < .0001 | | 0.798 |
| | Age | 0.157 | 0.010 | < .0001 | 0.240 | < .0001 |
| | Height* | 0.309 | 0.038 | < .0001 | | |
| | Weight* | 0.191 | 0.028 | < .0001 | | |
| | Body surface area | 13.123 | 0.034 | < .0001 | 15.781 | < .0001 |
| | Current smoker | | | 0.448 | | |
| | Ex-smoker | 2.611 | 0.008 | < .0001 | | 0.753 |
| | Hypertension | 1.498 | 0.003 | 0.002 | | 0.463 |
| | DM | 1.387 | 0.001 | 0.026 | | 0.928 |
| | HbA1c | 0.668 | 0.002 | 0.014 | | 0.833 |
| | Cholesterol | -0.021 | 0.004 | < .0001 | | 0.283 |
| | Triglyceride | 0.005 | 0.001 | 0.045 | | 0.667 |

Coeff., regression coefficient; HbA1c, glycated hemoglobin

*Height, Weight and Body mass index was not used for the multilinear analysis due to multicollinearity

Table 4

Linear and Multilinear Regression of Common Iliac Artery (CIA) and Iliac Artery (Common Iliac to External Iliac Artery) Diameter and Length with Variables

| | | Linear Regression | | | Multilinear Regression | |
|---|---|---|---|---|---|---|
| | **Variable** | **Coeff.** | $R^2$ | **P** | **Coeff.** | **P** |
| CIA Diameter | Female sex | -1.644 | 0.217 | < .0001 | -0.621 | < .0001 |
| | Age | 0.026 | 0.018 | < .0001 | 0.048 | < .0001 |
| | Height* | 0.084 | 0.175 | < .0001 | | |
| | Weight* | 0.071 | 0.246 | < .0001 | | |
| | Body surface area | 4.533 | 0.257 | < .0001 | 4.099 | < .0001 |
| | Current smoker | 0.452 | 0.012 | < .0001 | | 0.932 |
| | Ex-smoker | 0.967 | 0.073 | < .0001 | | 0.332 |
| | Hypertension | 0.581 | 0.025 | < .0001 | 0.122 | 0.018 |
| | DM | 0.344 | 0.005 | < .0001 | | 0.954 |
| | HbA1c | 0.131 | 0.004 | < .0001 | -0.067 | 0.020 |
| | Cholesterol | -0.005 | 0.015 | < .0001 | | 0.557 |
| | Triglyceride | 0.002 | 0.006 | < .0001 | -0.001 | < .0001 |
| CIA Length | Female sex | -1.107 | 0.001 | 0.025 | | 0.369 |
| | Age | -0.023 | 0.000 | 0.410 | | |
| | Height* | 0.124 | 0.005 | < .0001 | | |
| | Weight* | 0.078 | 0.004 | < .0001 | | |
| | Body surface area | 5.222 | 0.005 | < .0001 | 5.222 | < .0001 |
| | Current smoker | | | 0.372 | | |
| | Ex-smoker | 0.876 | 0.001 | 0.081 | | 0.710 |
| | Hypertension | | | 0.881 | | |
| | DM | | | 0.992 | | |
| | HbA1c | | | 0.267 | | |
| | Cholesterol | | | 0.193 | | |
| | Triglyceride | | | 0.898 | | |
| Iliac artery | Female sex | -1.575 | 0.254 | < .0001 | -0.636 | < .0001 |

| Diameter | | Linear Regression | | | Multilinear Regression | |
|---|---|---|---|---|---|---|
| | Age | 0.018 | 0.010 | < .0001 | 0.040 | < .0001 |
| | Height* | 0.083 | 0.217 | < .0001 | | |
| | Weight* | 0.067 | 0.278 | < .0001 | | |
| | Body surface area | 4.314 | 0.296 | < .0001 | 3.794 | < .0001 |
| | Current smoker | 0.411 | 0.012 | < .0001 | | |
| | Ex-smoker | 0.930 | 0.086 | < .0001 | | |
| | Hypertension | 0.474 | 0.021 | < .0001 | | |
| | DM | 0.237 | 0.003 | 0.001 | | |
| | HbA1c | 0.077 | 0.002 | 0.011 | -0.093 | < .0001 |
| | Cholesterol | -0.004 | 0.014 | < .0001 | | |
| | Triglyceride | 0.002 | 0.008 | < .0001 | -0.001 | < .0001 |
| Iliac artery Length | Female sex | -12.685 | 0.110 | < .0001 | -3.281 | < .0001 |
| | Age | 0.098 | 0.002 | < .0001 | 0.275 | < .0001 |
| | Height* | 0.905 | 0.173 | < .0001 | | |
| | Weight* | 0.583 | 0.142 | < .0001 | | |
| | Body surface area | 39.489 | 0.166 | < .0001 | 39.661 | < .0001 |
| | Current smoker | 1.840 | 0.002 | 0.014 | -2.431 | 0.001 |
| | Ex-smoker | 7.780 | 0.040 | < .0001 | | 0.529 |
| | Hypertension | 4.211 | 0.011 | < .0001 | | 0.280 |
| | DM | 1.591 | 0.001 | 0.062 | | 0.125 |
| | HbA1c | | | 0.921 | | |
| | Cholesterol | -0.037 | 0.007 | < .0001 | | 0.782 |
| | Triglyceride | 0.010 | 0.002 | 0.003 | -0.011 | 0.001 |

# Difference between men and women in diameter and length when matching BSA

When BSAs of men and women were matched, a total of 462 pairs were obtained (BSA range, 1.4–2.2). There was a significant difference in diameters between matched men and women ($P < .05$, Fig. 3-A). The difference between men and women was 1.26 [95% CI, 1.03–1.50] for the infrarenal aorta, 1.14 [95% CI, 0.60–1.38] for the lower abdominal aorta, 0.60 [95% CI, 0.42–0.78] for the CIA, and 0.62 [95% CI, 0.46–0.77] for the iliac artery. The length of the aorta was significantly longer in women ($P$= .001), while the length of the iliac artery was longer in men ($P$= .010) (Fig. 3-B). The difference in the aortic length and iliac artery was 2.77 [95% CI, 1.13–4.4] and 2.58 [95% CI, 0.62–4.53], respectively. There was no significant difference in CIA length ($P$= .613, Fig. 3-B).

# Discussion

Aorta and iliac artery size are considered essential in the diagnosis of aneurysm and the prediction of future aneurysmal rupture. The generally accepted definition of arterial aneurysm is a focal and persistent vessel dilation of 150% or more versus the expected normal diameter of the artery in question.[1] An association between age, sex, and body surface area and the normal diameter of the artery was proposed, but simpler definitions were then suggested since the effect on aortic diameter was not substantial.[13] Previous studies demonstrated that the normal IAD is slightly less than 20 mm in elderly men.[1,14] Accordingly, AAA in this population was defined as an IAD ≥ 30 mm.[15]

AAA is usually asymptomatic until rupture, and mortality can reach 85–90% in cases of rupture.[16] Several large studies have shown that screening for this condition reduces aneurysm-related mortality [17,18], and it is recommended in European guidelines for all elderly men and in American guidelines for elderly women and men with a history of tobacco use.[19,20] The frequency of follow-up imaging depends on initial artery diameter, considering the increased risk of rupture.[20] In addition to a large initial aneurysm diameter, female sex is a known independent risk factor associated with rupture as well as a worse outcome.[21–23] Interestingly, rupture occurs at aneurysm diameters of 5 to 10 mm smaller in women than in men.[24] One of the potential reasons is that an aneurysm of a given diameter in women with relatively smaller aortas due to smaller body size represents a greater relative dilatation and thus more advanced disease of the aorta than an aneurysm of the same diameter in men.[25] Therefore, it seems crucial that we identify the reference value of the IAD, particularly according to sex.

In our study on healthy Asian cohorts, mean aortic diameter was 17.490 ± 2.110 mm. When divided by sex, mean diameter of the aorta was 18.377 ± 1.766 mm in men and 15.884 ± 1.694 mm in women. The difference in mean value between them was 2.493 mm, larger than the previous report of 1.4 mm from the Veterans Affairs Cooperative Study.[26] As BSA was significantly larger in men ($P$< .001) and was the strongest factor that affected vessel diameter in our regression model ($P$< .001), we matched BSA to determine whether a difference in the diameter between sex was derived from BSA difference. Even after BSA was corrected, the difference in the diameter between men and women remained in all measured diameters ($P$< .001). Therefore, considering intersex differences in the diagnosis of diseases related to arterial diameter seems necessary.

The comparison of our data with those of previous reports from other countries using a one-sample *t* test revealed significant differences. The Veterans Affairs Cooperative Study reported that the aortic diameters measured below and above the renal arteries on ultrasonography for male patients were 20 ± 3 and 21 ± 3 mm, respectively.[26] When we compared those values with our data on diameters measured at the levels of the SMA and lowest renal artery, our data were significantly smaller than both diameters ($p < 0.001$ for both). The mean infrarenal abdominal aortic diameters on CT scan in the Framingham Heart Study for men and women were 19.3 ± 2.9 and 16.7 ± 1.8 mm, respectively, which were significantly larger than our values ($p < 0.001$ for both).[27] The mean aortic diameter at the bifurcation level was 18.7 ± 2.7 mm for men and 16 ± 1.7 mm for women, significantly larger than our values ($p < 0.001$ for both).[27] In a study of a Turkish population, on ultrasonography, the mean subdiaphragmatic aortic diameters were 18 ± 3 mm for women and 19 ± 4 mm for men, while the mean aortic diameters at the bifurcation level were 15 ± 3 mm for women and 16 ± 4 mm for men.[28] Compared with the diameter at the level of the SMA and bifurcation, the mean diameter in women was significantly smaller than that in men in our study ($p < 0.001$ for all). In an Indian study, the mean diameters of the suprarenal and infrarenal abdominal aortas measured at the T12 and L3 vertebral levels on CT scan were 19.0 ± 2.3 and 13.8 ± 1.9 mm for men and 17.1 ± 2.3 and 12.0 ± 1.6 mm for women, respectively.[29] Compared with the diameter at the level of the SMA and bifurcation, all the values were significantly larger in our study ($p < 0.001$ for all). In a Chinese population, the inner diameter of the infrarenal aorta on CT scan was 16.49 ± 2.12 mm for men and 14.50 ± 1.73 mm for women; all the values in our study were significantly larger than these results ($p < 0.001$ for all).[30] These results demonstrate differences among geographic regions. However, this finding is limited because the comparisons did not involve equal modalities and included anatomical levels with different measurements. An aneurysm diameter measured on standard axial CT is generally > 2 mm larger than when measured on ultrasonography.[20] Moreover, the actual difference was ≤ 2.5 mm. For example, the difference between the data from our study and those from the Framingham Heart Study was < 1 mm (0.92 mm for men and 0.81 mm for women) despite the statistical significance.[27] The clinical significance requires reevaluation with regard to the actual risk of rupture and the establishment of different surveillance criteria.

The strength of our study was that we used data from a healthy population without atherosclerotic steno-occlusive disease on CT scan. Because the artery tends to gets larger with the progression of the atherosclerotic disease; thus, the reference diameter needs to be evaluated from the normal population. Under the Korean health insurance system, people can opt to undergo a CT scan as part of their medical checkup. This is why we could obtain data from normal subjects for this analysis. Second, we investigated intersex difference in diameters with excluding the effect of BSA based on the large sample size. Lastly, we used 3D reconstruction to extract a centerline, avoid a parallax error, and increase reproducibility. When we evaluated intraobserver variability, reproducibility proved relatively efficient for obtaining reliable sizing data.

In conclusion, we obtained the reference diameters of the abdominal aorta of 17.490 ± 2.110 mm overall, 18.377 ± 1.766 mm in men, and 15.884 ± 1.694 mm in women in a Korean healthy cohort, which was smaller than Westerners. Arterial diameter increased with male sex, older age, and increased BSA, and the aortic diameters were larger in men than in women with the same BSA.

# Declarations

### Author contributions

TW.K., H.K., HK.K., and WH.K. contributed to the design, E.C., S.J. and Y.H. performed the measurements, TW.K., YP.C. and J.C. were involved in planning and supervised the work, H.K. and TW.K. performed the analysis, drafted the manuscript and designed the figures. YP.C. aided in interpreting the results and worked on the manuscript. All authors discussed the results and commented on the manuscript.

### Conflicts of Interest

None


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# References


1. Johnston, K. W. *et al.* Suggested standards for reporting on arterial aneurysms. Subcommittee on Reporting Standards for Arterial Aneurysms, Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery and North American Chapter, International Society for Cardiovascular Surgery. *J Vasc Surg* **13**, 452-458, doi:10.1067/mva.1991.26737 (1991).
2. Hirsch, A. T. *et al.* ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. *Circulation* **113**, e463-654, doi:10.1161/CIRCULATIONAHA.106.174526 (2006).
3. Chaikof, E. L. *et al.* The care of patients with an abdominal aortic aneurysm: the Society for Vascular Surgery practice guidelines. *J Vasc Surg* **50**, S2-49, doi:10.1016/j.jvs.2009.07.002 (2009).
4. Mortality results for randomised controlled trial of early elective surgery or ultrasonographic surveillance for small abdominal aortic aneurysms. The UK Small Aneurysm Trial Participants. *Lancet* **352**, 1649-1655 (1998).

5. Lederle, F. A. *et al.* Rupture rate of large abdominal aortic aneurysms in patients refusing or unfit for elective repair. *Jama* **287**, 2968-2972, doi:10.1001/jama.287.22.2968 (2002).
6. Powell, J. T. *et al.* Long-term outcomes of immediate repair compared with surveillance of small abdominal aortic aneurysms. *The New England journal of medicine* **346**, 1445-1452, doi:10.1056/NEJMoa013527 (2002).
7. Brewster, D. C. *et al.* Guidelines for the treatment of abdominal aortic aneurysms - Report of a subcommittee of the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery. *Journal of Vascular Surgery* **37**, 1106-1117, doi:10.1067/mva.2003.363 (2003).
8. Lo, R. C. *et al.* Relative importance of aneurysm diameter and body size for predicting abdominal aortic aneurysm rupture in men and women. *J Vasc Surg* **59**, 1209-1216, doi:10.1016/j.jvs.2013.10.104 (2014).
9. Joh, J. H., Ahn, H.-J. & Park, H.-C. Reference diameters of the abdominal aorta and iliac arteries in the Korean population. *Yonsei Med J* **54**, 48-54, doi:10.3349/ymj.2013.54.1.48 (2013).
10. Lorbeer, R. *et al.* Reference values of vessel diameters, stenosis prevalence, and arterial variations of the lower limb arteries in a male population sample using contrast-enhanced MR angiography. *PloS one* **13**, e0197559, doi:10.1371/journal.pone.0197559 (2018).
11. Pedersen, O. M., Aslaksen, A. & Vik-Mo, H. Ultrasound measurement of the luminal diameter of the abdominal aorta and iliac arteries in patients without vascular disease. *Journal of Vascular Surgery* **17**, 596-601, doi:10.1016/0741-5214(93)90161-E (1993).
12. Mosteller, R. D. Simplified calculation of body-surface area. *The New England journal of medicine* **317**, 1098, doi:10.1056/nejm198710223171717 (1987).
13. Lederle, F. A. *et al.* Prevalence and associations of abdominal aortic aneurysm detected through screening. Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Group. *Annals of internal medicine* **126**, 441-449, doi:10.7326/0003-4819-126-6-199703150-00004 (1997).
14. Evans, G. H., Stansby, G. & Hamilton, G. Suggested standards for reporting on arterial aneurysms. *J Vasc Surg* **15**, 456, doi:10.1016/0741-5214(92)90269-e (1992).
15. Starck, J. *et al.* A significant correlation between body surface area and infrarenal aortic diameter is detected in a large screening population with possibly clinical implications. *International angiology : a journal of the International Union of Angiology* **38**, 395-401, doi:10.23736/s0392-9590.19.04071-9 (2019).
16. Kent, K. C. Clinical practice. Abdominal aortic aneurysms. *The New England journal of medicine* **371**, 2101-2108, doi:10.1056/NEJMcp1401430 (2014).
17. Legemate, D. A. Population screening reduces mortality rate from aortic aneurysm in men. *The British journal of surgery* **87**, 1734, doi:10.1046/j.1365-2168.2000.01689-6.x (2000).
18. Lindholt, J. S., Juul, S., Fasting, H. & Henneberg, E. W. Hospital costs and benefits of screening for abdominal aortic aneurysms. Results from a randomised population screening trial. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery* **23**, 55-60, doi:10.1053/ejvs.2001.1534 (2002).

19. Wanhainen, A. *et al.* Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. *European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery* **57**, 8-93, doi:10.1016/j.ejvs.2018.09.020 (2019).
20. Chaikof, E. L. *et al.* The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. *J Vasc Surg* **67**, 2-77 e72, doi:10.1016/j.jvs.2017.10.044 (2018).
21. Brown, P. M., Zelt, D. T. & Sobolev, B. The risk of rupture in untreated aneurysms: The impact of size, gender, and expansion rate. *Journal of Vascular Surgery* **37**, 280-284, doi:https://doi.org/10.1067/mva.2003.119 (2003).
22. Norman, P. E. & Powell, J. T. Abdominal aortic aneurysm: the prognosis in women is worse than in men. *Circulation* **115**, 2865-2869, doi:10.1161/circulationaha.106.671859 (2007).
23. Brown, L. C., Powell, J. T. & with, T. U. K. S. A. T. P. Risk Factors for Aneurysm Rupture in Patients Kept Under Ultrasound Surveillance. *Annals of Surgery* **230**, 289 (1999).
24. Lo, R. C. *et al.* Relative importance of aneurysm diameter and body size for predicting abdominal aortic aneurysm rupture in men and women. *Journal of Vascular Surgery* **59**, 1209-1216, doi:https://doi.org/10.1016/j.jvs.2013.10.104 (2014).
25. Forbes, T. L., Lawlor, D. K., DeRose, G. & Harris, K. A. Gender Differences in Relative Dilatation of Abdominal Aortic Aneurysms. *Annals of vascular surgery* **20**, 564-568, doi:https://doi.org/10.1007/S10016-006-9079-y (2006).
26. Lederle, F. A. *et al.* Relationship of age, gender, race, and body size to infrarenal aortic diameter. The Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Investigators. *J Vasc Surg* **26**, 595-601, doi:10.1016/s0741-5214(97)70057-0 (1997).
27. Rogers, I. S. *et al.* Distribution, determinants, and normal reference values of thoracic and abdominal aortic diameters by computed tomography (from the Framingham Heart Study). *Am J Cardiol* **111**, 1510-1516, doi:10.1016/j.amjcard.2013.01.306 (2013).
28. Sariosmanoglu, N. *et al.* A multicentre study of abdominal aorta diameters in a Turkish population. *J Int Med Res* **30**, 1-8, doi:10.1177/147323000203000101 (2002).
29. Jasper, A. *et al.* Evaluation of normal abdominal aortic diameters in the Indian population using computed tomography. *Journal of postgraduate medicine* **60**, 57-60, doi:10.4103/0022-3859.128813 (2014).
30. Wang, X., Zhao, W. J., Shen, Y. & Zhang, R. L. Normal Diameter and Growth Rate of Infrarenal Aorta and Common Iliac Artery in Chinese Population Measured by Contrast-Enhanced Computed Tomography. *Annals of vascular surgery*, doi:10.1016/j.avsg.2019.05.030 (2019).

# Figures

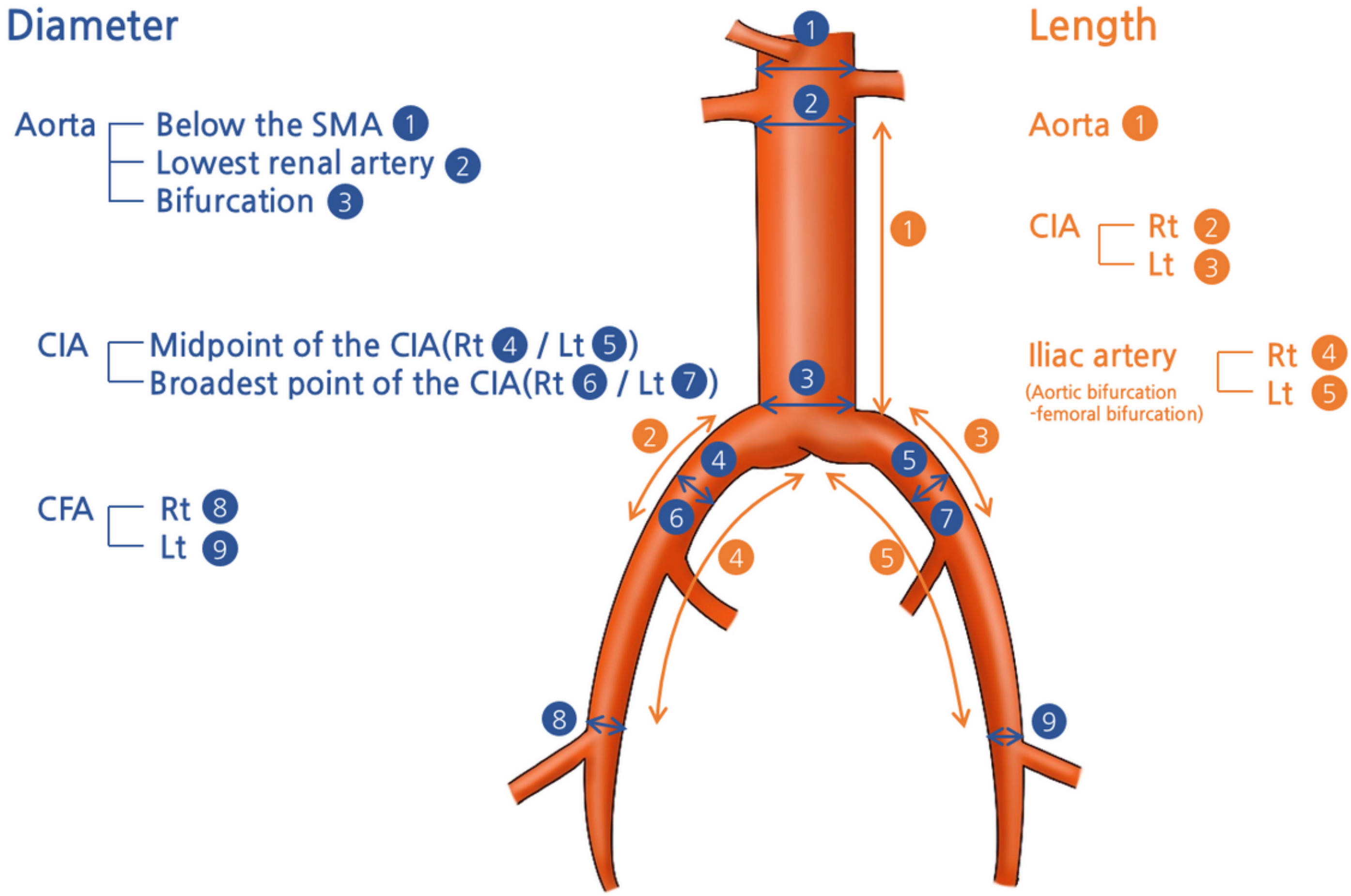
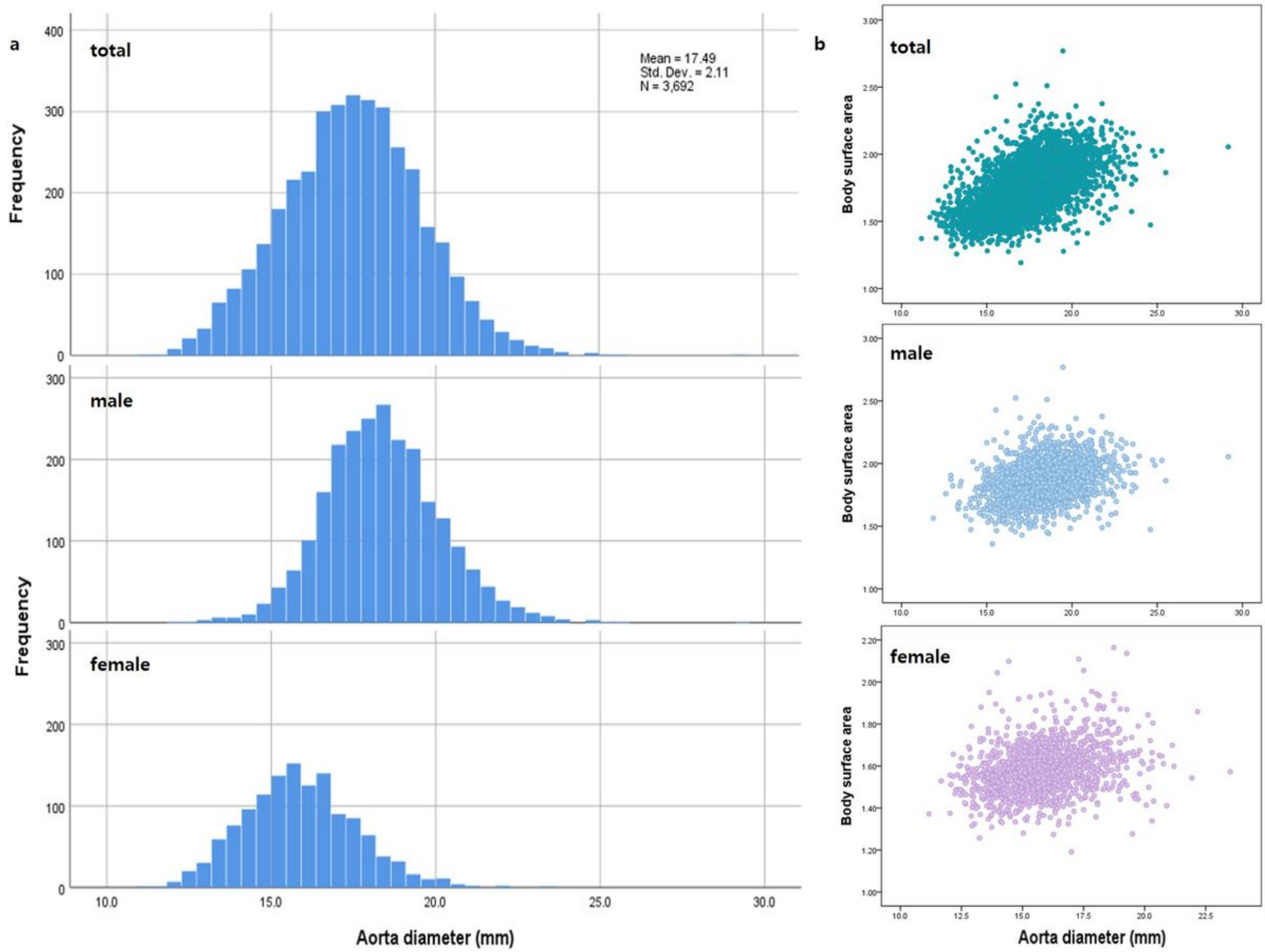


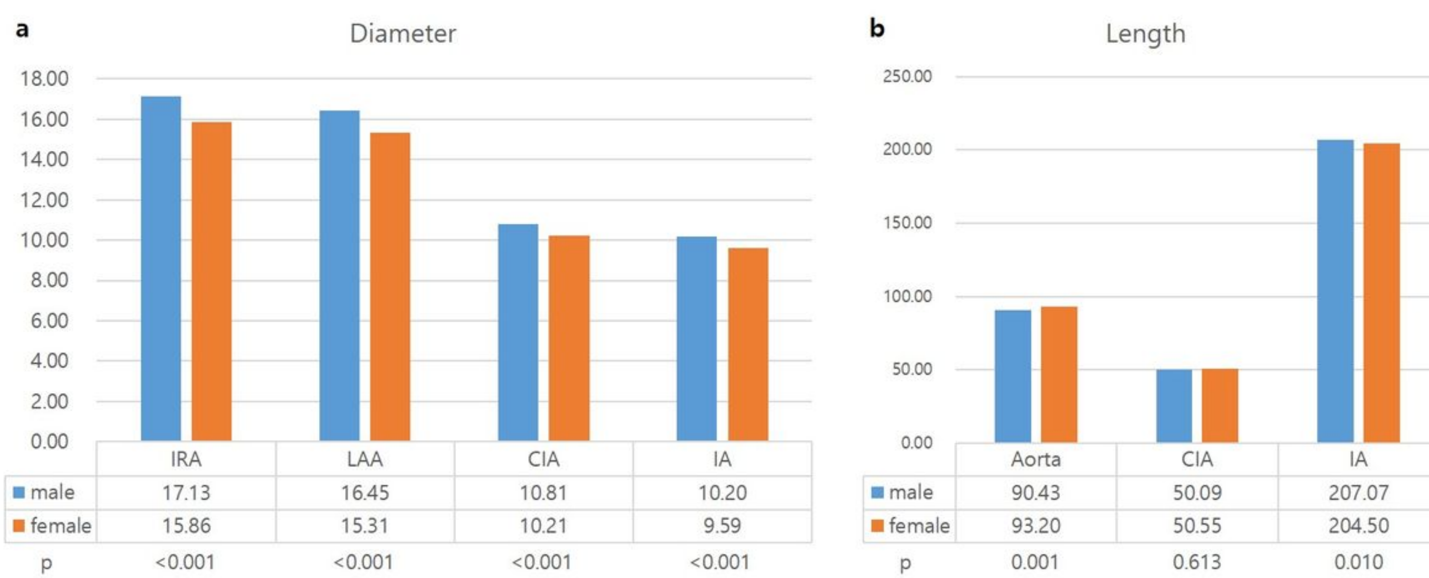

**Figure 1**

Diameter and length measurements by site. SMA, superior mesenteric artery; CIA, common iliac artery, CFA, common femoral artery.




## Figure 2

Distribution of aortic diameters by sex (a) and body surface area (b).



## Figure 3

Comparison of aortic diameters (a) and lengths (b) between men and women with the same body surface area. IRA, infrarenal aorta; LAA, lower abdominal aorta; CIA, common iliac artery; IA, iliac artery.