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Normative Subcarinal Angle on Normal Postero-Anterior Chest Radiographs in Nigerian Adults: A Reference for West Africa

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Abstract

Background

The subcarinal angle (SCA) is an indispensable tool that serve as an indirect radiological indicator of mediastinal and cardiac pathology used by cardiologist. Most published normative data derive from computed tomography (CT) studies conducted outside sub-Saharan Africa. Postero-anterior (PA) chest radiography provides a low-cost, widely accessible alternative that is particularly relevant in resource-limited clinical settings.

Objectives

To establish normative SCA values in Nigerian adults using PA chest radiographs; to compare the total SCA, right subcarinal angle (RSCA), and left subcarinal angle (LSCA) by gender; to correlate SCA with age and height; and to compare RSCA with LSCA.

Methods

A cross-sectional prospective study was conducted at the Radiology Department of Aminu Kano Teaching Hospital (AKTH), Kano, Nigeria. Normal PA chest radiographs of 90 adults aged 18 to 70 years (37 males, 53 females) were included. The SCA, RSCA, and LSCA were measured using a protractor on radiographs. Normality of the data was confirmed by Shapiro-Wilk test. Independent t-tests, a paired t-test, and Pearson correlation coefficients were applied using SPSS v20.0.

Results

The mean ± SD SCA was 58.31 ± 10.57°. Females had a significantly wider SCA than males (60.66° vs. 54.95°; p = 0.01). No significant gender difference was found for RSCA (p = 0.66), whereas LSCA differed significantly by gender (p = 0.003). The LSCA was significantly wider than the RSCA across all participants (30.78° vs. 27.76°; p = 0.002). SCA showed no significant correlation with age (r = 0.21, p = 0.049) or height (r = -0.15, p = 0.16).

Conclusion

The mean SCA on PA chest radiography in this Nigerian adult sample was 58.31°. The SCA was significantly influenced by gender but not by age or height. The LSCA was wider than the RSCA in both sexes. These normative values offer an initial reference standard for PA-based SCA assessment in Nigerian and West African clinical practice, where CT remains inaccessible to many patients.

Introduction

Cardiovascular diseases (CVD) are responsible for a multitude of deaths and disabilities in the world[1]. Nigeria is currently experiencing an epidemiological transition characterized by rapid urbanization and

lifestyle modifications, which have further increased the occurrence of cardiovascular disorders such as stroke, myocardial infarction, and heart failure[2]. Hypertension remains one of the most important modifiable risk factors associated with cardiovascular diseases and related complications[3]. The growing prevalence of CVD highlights the importance of early diagnosis and accurate radiographic assessment of thoracic structures, including the subcarinal angle, which provides an essential diagnostic tool in cardiopulmonary conditions.

The subcarinal angle (SCA) is the angle formed at the carina, the cartilaginous ridge that marks the bifurcation of the trachea into the right and left main bronchi. This bifurcation occurs at the approximate level of the fourth to fifth thoracic vertebra in line with the sternal angle, although respiratory phase and body posture can shift its position by one to two vertebral levels[4]. The SCA is also referred to in the literature as the tracheal bifurcation angle and the inter-bronchial angle.

The SCA holds clinical significance as a radiological indicator of mediastinal and cardiac pathology. An increase beyond the normal range has been associated with left atrial enlargement, generalized cardiomegaly, subcarinal lymphadenopathy, lobar collapse, and pericardial effusion[5,6]. The carina descends during deep inspiration, causing the bronchial tree to elongate and the SCA to narrow; expiration reverses this effect[6]. Accurate knowledge of normal SCA is therefore a prerequisite for the reliable identification of pathological angle changes. Taskin et al.[7] proposed that a carinal angle exceeding 100° is a reliable predictor of left atrial enlargement, while Murray et al.[8] subsequently demonstrated that tracheal bifurcation widening on chest radiographs is an insensitive and non-specific sign for this diagnosis, cautioning against its uncritical use.

The SCA is also relevant for procedural planning. Safe bronchoscopy and correct placement of double-lumen endotracheal tubes for one-lung ventilation in thoracic anesthesia require reliable reference values for the branching angles of the tracheobronchial tree[9].

Several imaging techniques have been used to characterize tracheobronchial anatomy, including cadaveric dissection, bronchography, virtual bronchoscopy, CT, magnetic resonance imaging, and PA chest radiography. CT is widely regarded as the reference standard, providing three-dimensional anatomical detail with minimal distortion of airway geometry[6]. Helical CT with minimum intensity projection (MinIP) reconstruction, which selectively displays low-density air-containing structures, has been applied to achieve particularly precise intraluminal measurement of the SCA[10,11]. However, CT delivers substantially greater radiation dose than plain radiography and, in many low-income and middle-income settings, is available only in urban tertiary centres[6]. PA chest radiography is inexpensive, widely available, and causes minimal disturbance of airway anatomy, making it a practical alternative for SCA measurement, as demonstrated by previous investigators[12,13,14].

Published normative SCA studies have been conducted primarily in South Asian and East Asian populations using CT[6,11,15,10] and using PA chest radiographs[12,13,14,8]. Jha et al.[13], in a PA-radiograph

normative study of 392 adults in Nepal, reported a mean SCA of 60.17° and additionally demonstrated a significant positive correlation between SCA and body mass index, underlining the influence of body habitus. Cadaveric normative data are available from India and other settings[5,16]. Empirical study and literature review reveal no normative SCA data specific to the Nigerian or broader West African population have been published. Establishing population-specific reference values is important because body habitus, chest configuration, and disease burden patterns may differ from populations in which prior normative data were generated. The present study therefore aimed to determine normative SCA values on PA chest radiographs in Nigerian adults at a tertiary hospital in Kano; to compare SCA, RSCA, and LSCA between male and female participants; to examine the relationship of SCA with age and height; and to compare RSCA with LSCA.

Methods

2.1 Study Design and Setting

This cross-sectional prospective study was conducted at the static X-ray unit of the Radiology Department of Aminu Kano Teaching Hospital (AKTH), Kano, Nigeria. AKTH is a 500-bed federal tertiary referral institution serving the north-western geopolitical zone of Nigeria.

2.2 Participant Selection

Adults aged 18 to 70 years referred for PA chest radiography during the study period were eligible for inclusion. Only radiographs formally reported as normal by a consultant radiologist were enrolled. Participants were excluded if they were younger than 18 or older than 70 years, if the radiograph was abnormal on radiologist reporting, or if they declined to participate. Additional exclusion criteria were a prior history of cardiothoracic surgery, tracheostomy, tracheal surgery, neck injury, or any documented intrathoracic condition likely to distort tracheobronchial anatomy. The same exclusion criteria were used by Khade et al.[6] and Parry et al.[10] to ensure radiologically normal tracheobronchial anatomy.

2.3 Sampling

A convenience sampling strategy was used. Consecutive eligible participants attending during the study period were enrolled until data collection was completed. A total of 90 participants (37 males and 53 females) were recruited.

2.4 Radiographic Technique

All examinations were performed using the standard erect PA chest projection. Participants stood facing the image receptor with the chin elevated and the median sagittal plane perpendicular to the receptor. The shoulders were rotated forward and pressed into contact with the receptor surface. Exposure was made at full arrested inspiration. A 35 x 43 cm or 35 x 35 cm cassette was selected according to thoracic dimensions. The horizontal central ray was directed at right angles to the receptor at the level of

the eighth thoracic vertebra (spinous process of T7). Each radiograph was assessed by the reporting radiologist before inclusion in the study.

2.5 Measurement of the Subcarinal Angle

Each PA chest radiograph was assessed on a viewing box under standardized lighting conditions. A reference line was drawn along the midline of the trachea to intersect the carina. Additional straight lines were drawn along the lower border of each main bronchus, meeting at the carina. The angle subtended between the tracheal midline reference and the lower border of the right main bronchus was recorded as the RSCA, and the corresponding angle on the left side was recorded as the LSCA. The total SCA was the sum of RSCA and LSCA. All angles were measured using a standard protractor. This method follows the approach described by Turner[17] and applied in prior normative studies[12,8,13].

2.6 Anthropometric Data

Participant height was measured in the standing position using a stadiometer. Age was obtained from the clinical request form with verbal confirmation from the participant.

2.7 Ethical Considerations

Ethical approval

was obtained from the College of Health Sciences Research Ethics Committee, Bayero University Kano (Reference: BUK/CHS/REC/VII/27). Written informed consent was obtained from all participants before data collection. Participant confidentiality was maintained throughout the study.

2.8 Data Analysis

Data were entered and analysed using IBM SPSS Statistics version 20.0. Continuous variables are reported as mean ± standard deviation (SD). The normality of continuous variables was assessed using the Shapiro–Wilk test prior to selecting statistical tests; all continuous variables satisfied the assumption of normality, justifying the use of parametric tests throughout. Differences in SCA, RSCA, and LSCA between male and female participants were examined using independent-samples t-tests. The within-participant difference between RSCA and LSCA was tested using a paired-samples t-test. The relationships between SCA and age, and between SCA and height, were examined using Pearson correlation coefficients. A two-tailed significance threshold of alpha = 0.05 was applied throughout.

Results

3.1 Participant Characteristics

A total of 90 normally reported PA chest radiographs met the inclusion criteria. The sample comprised 37 males (41.1%) and 53 females (58.9%); gender distribution is illustrated in Fig. 1. The mean ± SD age was 34.78 ± 12.60 years in males and 35.78 ± 14.40 years in females, with an overall mean ± SD of 35.08

± 13.00 years. Ages ranged from 18 to 70 years in both sexes. The overall mean ± SD height of participants was 1.63 ± 0.097 m. Anthropometric characteristics are summarized in Table 1.

Table 1
Anthropometric characteristics of participants (n = 90).

Variable	Male (n = 37)	Female (n = 53)	Total (n = 90)
Age (years)			
Mean ± SD	34.78 ± 12.60	35.78 ± 14.40	35.08 ± 13.00
Height (m), Mean ± SD	1.68 ± 0.09	1.60 ± 0.08	1.63 ± 0.097

Total Subcarinal Angle by Gender

The overall mean ± SD SCA was 58.31 ± 10.57°. Females showed a significantly wider SCA (60.66 ± 10.91°) compared with males (54.95 ± 9.20°), confirmed by independent t-test (t(88) = -2.60, p = 0.01).

3.2 Right Subcarinal Angle by Gender

The mean ± SD RSCA was 27.43 ± 4.60° in males and 27.98 ± 6.36° in females. The difference was not statistically significant (t(88) = -0.45, p = 0.66).

3.3 Left Subcarinal Angle by Gender

The mean ± SD LSCA was 27.78 ± 7.25° in males and 32.87 ± 8.07° in females. This difference was statistically significant (t(88) = -3.06, p = 0.003). All gender-stratified measurements are presented in Table 2.

Table 2
Subcarinal angle measurements by gender (independent-samples t-tests, df = 88).

Measurement	Male (n = 37) Mean ± SD	Female (n = 53) Mean ± SD	t	df	p value
Total SCA (°)	54.95 ± 9.20	60.66 ± 10.91	-2.60	88	0.010
RSCA (°)	27.43 ± 4.60	27.98 ± 6.36	-0.45	88	0.660
LSCA (°)	27.78 ± 7.25	32.87 ± 8.07	-3.06	88	0.003

SCA = total subcarinal angle; RSCA = right subcarinal angle; LSCA = left subcarinal angle; SD = standard deviation; df = degrees of freedom. Alpha = 0.05 for all comparisons.

3.4 Comparison of Right and Left Subcarinal Angles

Across all 90 participants, the mean ± SD RSCA was 27.76 ± 8.04° and the mean ± SD LSCA was 30.78 ± 5.68°. A paired t-test demonstrated that the LSCA was significantly wider than the RSCA, with a mean difference of -3.02 ± 9.17° (t(89) = -3.13, p = 0.002), as presented in Table 3.

Table 3
Paired comparison of right and left subcarinal angles across all participants (n = 90).

Comparison	Mean difference ± SD	t	df	p value
RSCA vs. LSCA (°)	-3.02 ± 9.17	-3.13	89	0.002

RSCA = right subcarinal angle; LSCA = left subcarinal angle; SD = standard deviation; df = degrees of freedom. A negative mean difference indicates LSCA > RSCA.

3.5 Correlations with Age and Height

Pearson correlation showed a weak positive but non-significant relationship between SCA and age (r = 0.21, p = 0.05). There was also a weak negative and non-significant correlation between SCA and height (r = -0.15, p = 0.16). These results are shown in Table 4.

Table 4
Pearson correlations between total SCA and anthropometric variables (n = 90).

Variable	r	p value	Interpretation
Age (years)	0.21	0.049	Weak positive; not significant
Height (m)	-0.15	0.160	Weak negative; not significant

3.6 Summary Comparison with Published Literature

Table 5 places the present findings in the context of published normative SCA studies.

Table 5
Summary of published normative subcarinal angle studies.

Author (year)	Method	n	Male SCA Mean (SD)	Female SCA Mean (SD)	Total SCA Mean (SD)
Alavi et al.[12]	PA CXR	87	56.40 (5.66)°	57.73 (6.37)°	57.16 (6.06)°
Haskin and Goodman[18]	PA CXR	100	NR	NR	60.8 (11.80)°
Chen JTT et al.[19]	PA CXR	54	NR	NR	62.3 ± 8.6
Murray et al.[8]	PA CXR	108	61.2 (13.1)°	63.6 (15.9)°	62.6 (14.8)°
Coppola et al.[20]	PA CXR	500	NR	NR	79.7 (37–105)
Choorat et al.[14]	PA CXR	NR	60.42°	63.46°	62.0 (12.62)°
Jha et al.[13]	PA CXR	392	59.17 (8.19)°	60.62 (7.49)°	60.17 (7.81)°
Karabulut[21]	CT	120	70 (16)°	77 (14)°	NR
Kamel et al.[22]	CT	60	76 (20)°	81 (20)°	78 (20)°
Mrudula and Krishnaiah[23]	Cadever	25	NR	NR	77.8 (50–130)
Fernandes and Pradhan[11]	CT (MinIP)	193	69.63 (2.75)°	69.90 (4.07)°	69.75 (3.38)°
Khade et al.[6]	CT	110	80.01 (12.53)°	79.75 (9.99)°	79.92 (11.60)°
Parry et al.[10]	CT (MinIP)	552	67.60 (14.55)°	78.90 (11.04)°	NR
Present study (2026)	PA CXR	90	54.95 ± 9.20°	60.66 ± 10.91°	58.31 (10.57)°

PA CXR = postero-anterior chest radiograph; CT = computed tomography; MinIP = minimum intensity projection; SD = standard deviation; NR = not reported; NS = not statistically significant. SCA values are means (SD) in degrees unless stated otherwise.

Discussion

This study provides the first normative SCA values derived from PA chest radiographs in a Nigerian adult population. The overall mean SCA of 58.31° is consistent with values from comparable plain-radiograph

normative studies. Alavi et al.[12], using chest radiographs in 87 subjects in the United States of age over 16 years, reported a mean SCA of 57.16 ± 6.06°, a value closely approximating the present finding. Jha et al.[13], in a recent PA-radiograph normative study of 392 Nepalese adults, reported a mean SCA of 60.17 ± 7.81°, also consistent with the present value. The agreement among these three plain-radiograph studies, conducted in different continents and populations, supports the validity and reproducibility of PA-radiograph-based SCA measurement. The present study extends this body of normative plain-radiograph data to a Nigerian population for the first time.

CT-based studies have consistently yielded wider mean SCA values than plain-radiograph studies. Khade et al.[6] reported a mean SCA of 79.92 ± 11.60° on CT in India, and Fernandes and Pradhan[11] reported a CT-derived mean of 69.75 ± 3.38° using MinIP reconstruction. The largest CT series to date, Parry et al.[10], studied 552 patients in India using MinIP and reported a wide overall SCA range of 41° to 104°, illustrating the broad normal variability inherent to CT measurement. The systematic difference between plain-radiograph and CT-derived values is attributable to modality differences: plain radiographs delineate only the intraluminal air-tissue interface, whereas CT with MinIP images the bronchial wall and lumen together, allowing measurement from outer wall to outer wall and producing consistently larger absolute angle values. This modality distinction must be borne in mind when comparing SCA values across published studies.

Females in the present study had a significantly wider SCA than males (60.66° vs. 54.95°, $p = 0.01$). This directional finding aligns with Alavi et al.[12], who also observed females to have a modestly wider angle (57.73° vs. 56.40°) on plain radiographs. The significantly wider female SCA on CT is also reported by Parry et al.[10], who found females to have a substantially wider mean SCA than males (78.90° vs. 67.60°, $p < 0.05$) in their large Indian cohort, and by Karabulut[21] and Kamel et al.[22]. By contrast, Jha et al.[13] found the difference between male (59.17°) and female (60.62°) SCA on PA radiographs to be non-significant ($p = 0.196$) in their Nepalese sample. The discrepancy between the present study and Jha et al. may reflect the substantially larger sample size in Jha's study ($n = 392$ vs. $n = 90$), which would dilute the detection of small absolute gender differences, or may reflect genuine population-specific differences in body habitus between Nepalese and Nigerian adult populations. It is proposed that in the present sample, the predominantly hyper-sthenic to sthenic body habitus of male participants, associated with a more vertically elongated mediastinum, may contribute to the narrower SCA compared with the predominantly asthenic to sthenic female participants. Khade et al.[6] and Fernandes and Pradhan[11] found no significant gender difference on CT, which may reflect both modality-specific differences and population-specific anthropometric effects.

The finding that the LSCA was significantly wider than the RSCA (30.78° vs. 27.76°, $p = 0.002$) is anatomically consistent with the spatial influence of the aortic arch and cardiac mass on the left main bronchus, which diverges more obliquely from the tracheal axis than the right. This asymmetry has been documented across imaging modalities. Daroszewski et al.[24], studying tracheobronchial angles in human fetuses using digital image analysis, reported mean RSCA and LSCA values of 26.9 ± 7.0° and

46.2 ± 8.0° respectively, confirming the LSCA > RSCA pattern from early development. Ulusoy et al.[9], using MDCT in 253 patients, reported mean right and left SCA of 34.5 ± 8.1° and 38.1 ± 8.9° respectively, again confirming left-predominance. Mrudula and Krishnaiah[23] reported RSCA of 39.68° and LSCA of 43.34° in cadaveric specimens, values wider than those of the present study, attributable to post-mortem tissue changes.

A specific finding of the present study is that the gender difference in subcarinal angle measurements was specific to the LSCA ($p = 0.003$) and was not observed for the RSCA ($p = 0.66$). This asymmetric gender effect has not been highlighted in prior published investigations, to the knowledge of the present authors. The LSCA, being more closely related to cardiac structures and the aortic arch, may be more sensitive to gender-associated differences in cardiac dimensions and mediastinal configuration. This observation warrants further investigation in larger, more representative samples.

The weak positive correlation between SCA and age ($r = 0.21$, $p = 0.05$) in the present study did not reach statistical significance. This contrasts with Jha et al.[13], who found a significant weak negative correlation between SCA and age on PA radiographs ($r = -0.168$, $p < 0.01$) in their larger Nepalese sample. Jha and colleagues proposed that progressive calcification of tracheal cartilage rings after the age of 40 years reduces tracheobronchial elasticity and contributes to a narrower SCA with advancing age. The absence of a significant correlation in the present study may reflect limited statistical power in the smaller sample ($n = 90$) to detect a correlation of this magnitude. The age-independence of CT-derived SCA was also reported by Khade et al.[6] and Fernandes and Pradhan[11], suggesting that the age-SCA relationship may be modality-specific or population-specific.

The weak negative correlation between SCA and height ($r = -0.15$, $p = 0.16$) in the present study did not reach statistical significance. The direction is physiologically plausible: taller individuals tend toward more vertically elongated mediastinal structures, potentially narrowing the bronchial branching angle. Body mass index (BMI) was not collected in the present study, which is a notable limitation. Jha et al.[13] found a significant positive correlation between SCA and BMI ($r = 0.100$, $p < 0.05$) and proposed that hyper-sthenic body habitus is associated with a wider SCA. Fernandes and Pradhan[11] similarly examined body habitus in their CT-based study. Future normative studies in Nigerian populations should include BMI as a variable, as adiposity patterns and body composition differ substantially between West African and South Asian populations.

Several limitations of the present study merit acknowledgement. The sample was recruited by convenience at a single institution, which restricts the generalizability of the findings. The sample size of 90, while sufficient to detect the reported gender differences, provides limited power for subgroup analyses and for detecting small correlations. Measurement was performed using a protractor on plain film, and inter-rater and intra-rater reliability were not formally quantified; future studies should report intra-class correlation coefficients for repeated measurements, as this is now required by most peer-reviewed journals publishing normative radiographic data. The study did not capture BMI or ethnic group

within the Nigerian population, and further multicenter research is needed to establish whether SCA values differ across Nigerian ethnic and geographic groups.

Conclusion

This normative study established a mean SCA of 58.31 ± 10.57° on PA chest radiography in Nigerian adults attending a tertiary referral hospital in Kano, consistent with comparable plain-radiograph normative data from other populations. The SCA was significantly wider in females than in males and was independent of age and height within the range studied. The LSCA was consistently wider than the RSCA, and gender differences were specific to the LSCA. These values offer an initial normative reference for PA-based SCA assessment in Nigerian and West African clinical practice, where CT remains inaccessible to many patients. Multicenter studies incorporating larger samples, formal measurement reliability testing, BMI, and ethnic group data are recommended to consolidate and validate these reference values.

Abbreviations

Abbreviation	Full Term
SCA	Subcarinal Angle
PA	Postero-Anterior
CT	Computed Tomography
CXR	Chest Radiograph
CVD	Cardiovascular Disease
AKTH	Aminu Kano Teaching Hospital
BUK	Bayero University, Kano
CHS-REC	College of Health Sciences Research Ethics Committee
LSCA	Left Subcarinal Angle
RSCA	Right Subcarinal Angle
SD	Standard Deviation
NR	Not Reported
SPSS	Statistical Package for the Social Sciences

Declarations

Ethics Approval

Ethical approval for this study was obtained from the College of Health Sciences Research Ethics Committee (CHS-REC), Bayero University, Kano, under reference number BUK/CHS/REC/VII/27. The study was carried out in full accordance with the principles of the Declaration of Helsinki and all applicable local regulatory requirements governing research involving human participants.

Consent for publication

Not applicable.

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Author Contribution

ZUA conceived and designed the study, obtained ethical approval, and carried out data collection. IBU performed the statistical analysis and drafted the manuscript. MA supervised the project, provided critical intellectual input, and reviewed the manuscript for important content. All authors read and approved the final version submitted for publication.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions governing patient information.

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Figures

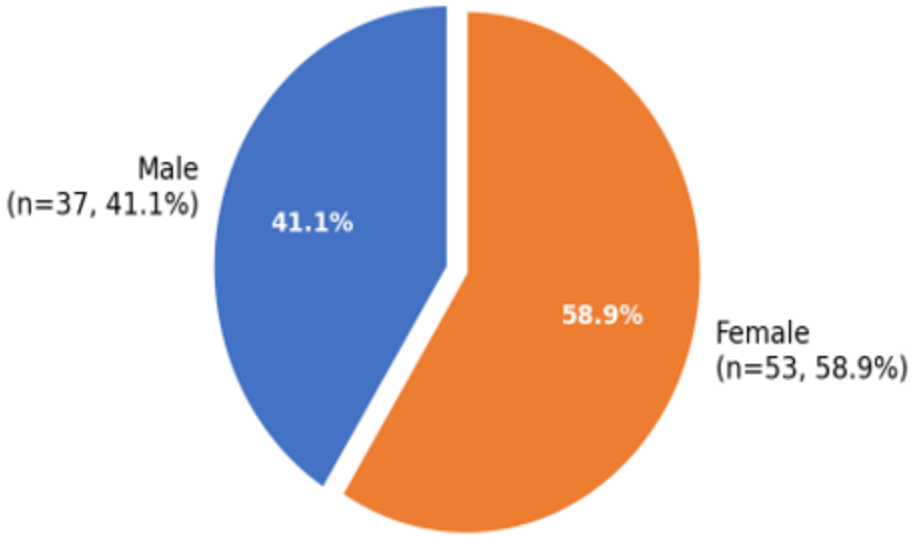

Figure 1

Gender distribution of participants