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The Impact of Body Habitus and Body Mass Index on Rotation in Chest Radiographs: A Single Center Study

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Abstract

Background: Chest radiograph shows the anatomical structures of the thorax and it is one of the most frequently performed radiographic examinations globally. With accurate patient's positioning that is devoid of rotation and also putting patient's body morphology into consideration, chest radiograph revealed significant information of most abnormalities associated with the thoracic region. This study is aimed at evaluating the impact of body morphology on rotation in PA radiographs.

Materials and methods: A prospective study design was adopted in this study to evaluate the effects of body habitus and body mass index on rotation identified in chest radiographs and was conducted in single centre in Lagos State, Nigeria from September 2018 to February 2019. Ethical approval for this study was obtained from the Institutional Research Review Board of the study centre. The procedure for the study was adequately explained to the subjects and their consents were properly sought. All standard protocols and techniques were adopted to obtain the PA chest radiographs by qualified Radiographer. The obtained information was treated with high level of confidentiality. Variables such as age, sex, Body Mass Index (BMI), body habitus and patterns of rotation were collected using data capture sheet. The obtained data were analyzed using Statistical Package for Social Sciences (SPSS) version 22. Both descriptive statistics (mean, standard deviation, pie chart and bar chart) and inferential (Chi-square) statistics were used for statistical analysis with p-value<0.05 set for level statistical significance.

Results: Out of 200 participants, those with normal weight were highest 60 (30%). BMI showed statistically significant relationships with right and left rotations at (p<0.05). Sthenic body habitus was highest 100 (50%). Body habitus showed statistically significant relationships with right and left rotations at (p<0.05).Of the total participants, males were 48.5% (n=97), while females were 103 (51.5%). There was statistically significant relationship between gender and rotation at (X^2=69.688, df=1 and p=0.000).Out of 98 cases of rotations identified in this study, 54.1% (n=53) were found to the right when compared to rotation to the left, which is 45(45.9%). Chi-square (X^2) test showed that there was statistically significance with these patterns of rotation at (X^2=156.989, df=1 and p=0.000).

Conclusion: Body morphology effect rotation on chest radiographs. Based on this study, we concluded that increment in BMI and body habitus are associated with increment in rotation on chest radiographs. Rotation on chest radiographs is more frequent in females. BMI, body habitus and gender should be considered when assessing a radiograph with rotation.

Keywords: Body mass index; Body habitus; Chest radiograph; Rotation

Introduction

Chest radiography is one of the most commonly conducted medical imaging examinations globally [1-4], even with the technological development of different imaging modalities and processes of acquisition of images. Clinical imaging plays a central role in health care as it assists radiologists and clinicians in the diagnosis and management of diseases.

Despite a small but increasing hazard of diagnostic x-ray to humans [5], the chest x-ray remains a simple, easy, cheap, readily available and most informative examination. Routinely acquired in the erect Posteroanterior (PA) position with the participants in full inspiration [2,4,6], a chest radiograph displays considerable amounts of medical information with accurate patient positioning. However, it is important to appreciate the limitations of this technique. Begg [7] noted that it is important to evaluate the chest radiograph for technical adequacy to determine if the chest radiograph is satisfactory for interpretation or whether certain artifacts may have been introduced in the course of producing the chest radiograph that may mimic pathology. According to Lloyd-Jones [8], there are some technical factors that can help us to determine if a chest radiograph is adequate for interpretation. These factors include; penetration, inspiration, rotation, magnification, angulation, inclusion and artifacts. Rotation is one of the important technical factors that can distort the diagnostic quality of a chest radiograph [9] and is likely to occur, according to Jaeger et al. [10] in images obtained with portable machines in non-hospital settings and mobile screening stations in rural areas and in poorly observed chest radiograph screening protocols. Ahmad [11] noted that any degree of rotation can distort the mediastinal borders and compromise the lungs appearance resulting in misinterpretation of the radiograph. In radiological practice the easiest way to confirm whether a chest radiograph is rotated is by studying the position of the medial ends of the clavicles in relation to the spinous process, because the spinous processes should lie equidistant between the medial ends of the clavicles [4,7,9].

The role of body morphology in radiology could very well be a more general issue not necessarily limited to radiographs. Obesity has a strong effect in all medical specialties [12,13]. Obese body habitus adversely impacts image quality [13], despite the improvement in technology and techniques. According to Rajapakse and Chang [14], large body habitus can degrade image quality in all medical imaging modalities, sometimes making it difficult to obtain accurate clinical interpretations. Le et al. [15] documented that radiographers relied heavily on visual and tactile senses to locate and palpate structures for diagnostic imaging, however, the thick layer of adipose tissue obscuring body landmarks hinder accurate positioning, making repeat projections due to positioning error [16].

There is paucity of data on the impact of body morphology in radiographic appearances of rotation in our setting. To the best of our knowledge this is the first study designed to investigate the impact of body morphology in radiographic appearance of rotation on chest radiograph. This study also aimed to investigate if demographic parameters such as age, gender, height and weight have any impact on rotation in chest radiograph.

Materials and Methods

A cross-sectional prospective study design was adopted in this study to evaluate the effects of body habitus and body mass index on rotation identified in chest radiographs. This study was conducted in a single centre in Lagos State, Nigeria from September 2018 to February 2019. Ethical approval for this study was obtained from the Institutional Research Review Board of the study center. The procedures were explained to the participants and their consents were properly sought using written informed consent form. The participants were also informed of their option to withdraw from the study without losing any health care given by the hospital.

A sample size of two hundred (200) apparently healthy subjects was recruited for this study. The sample size was determined by using the G-power software application. All adult participants within age range of 18-50 years referred for PA chest radiographic examination within the period of this study, those who consented to participate and were able to assume standing position during the procedures, were included in this study. A non-probability, convenient sampling method was used for selection of the participants.

The demographic and anthropometric variables such age, gender, weight, height, Body Mass Index (BMI) and body habitus were obtained before the procedure. Heights and weights were measured with RGZ-160 digital weighing scale which had apparatus for height measurement. The height and weight measurements were obtained two times and the averages of the measurements were used. The BMI, was calculated from the quotient of the body mass (kg) divided by the square of the height with the unit of kg/m^2. The body habitus was determined with measuring tape.

All the chest radiographic examinations were performed by a qualified Radiographer using standard protocols (35 cm × 35 cm and 35 cm × 43 cm cassette depending on the participants' size, Focus to Film Distance (FFD) of 180 cm, PA projection) and parameters using Generic static x-ray machine. All the chest radiographs of the participants were evaluated for rotation. Rotation on PA chest radiographs was measured and analyzed from the distance between the medial heads of the clavicles to adjacent appearing vertebral spinous processes in the upper thoracic region [9,17]. The identified rotation cases were categorized into gender, age and patterns (right and left) side rotations. The obtained data were collected using structured proforma and were analyzed using SPSS version 22. Both descriptive and inferential (Chi-square test) statistics were adopted for data statistical analysis with level of statistical significance set at $p<0.05$.

Results

Out of 200 participants, rotation on chest radiographs accounted for 98 (49%) while non-rotation was 102 (51%). Participants with Body Mass Index (BMI) of 18.50-24.50 kg/m^2 (Normal weight) were highest 60 (30%) and the least were those with BMI of<18.50 kg/m^2, which is 41 (20.5%) **(Table 1).** Of the 49% cases of rotation on chest radiograph identified in this study, obese participants were highest 21% and the least was normal weight 6% **(Table 1).**

Table 1 Categorization of BMI based on rotation and non-rotation in chest radiographs.

Categorization of BMI (Kg/m$^{2)}$	Frequency and Percentage% (N)		Total
	Rotation	Non - Rotation	
Underweight (<18.50 kg/m^2)	8% (16)	12.5% (25)	26.5% (41)
Normal weight (18.50-24.50 kg/m^2)	6% (12)	24% (48)	30%(60)
Overweight (25.00-29.99 kg/m^2)	14% (28)	8.5% (17)	22.5% (45)
Obese (30.00 kg/m^2)and above	21% (42)	6% (12)	27% (54)

The Chi-square test showed that there were statistically significant relationships between all the categories of the body mass index and left and right rotation at p<0.05, Underweight (Left rotation: X^2=82.600, df=9, p=0.000; right rotation: X^2= 83.610, df=9, p=0.001) and Obese (Left rotation: X^2= 51.945, df=9, p=0.000; right rotation: X^2=53.924, df=1, p=0.000) **(Table 2).**

Table 2 Relationship between Body mass index (BMI) and patterns of rotation in chest radiographs.

Categorization of Body Mass Index	Patterns of Rotation% (N)					
	Left Rotation (LR)			Right Rotation		
	X^2	df	P Value	X^2	df	P Value
Under-weight (<18.50 kg/m^2)	82.600	9	0.000	83.610	9	0.001
Normal-weight (18.50-24.50 kg/m^2)	117.941	9	0.000	116.813	9	0.000
Overweight (25.00-29.99 kg/m^2)	114.936	9	0.000	115.825	9	0.000
30.00 kg/m^2 and above (Obese)	51.945	1	0.000	53.924	1	0.000

Out of the total participants included in this study, those with sthenic body habitus were highest 100 (50%) and the least were those with hypersthenic body habitus, which is 10 (5%) **(Table 3).** Of the 49% cases of rotation identified in this study, those with sthenic body habitus were highest 28% (n=56), followed by hyposthenic participants 10.5% (n=21) and the least were those with hypersthenic body habitus 3% (n=6) **(Table 3).**

Table 3 Categorization of body habitus based on rotation and non-rotation in chest radiographs.

Categorization of Body Habitus	Frequency and Percentage (%) (N)		Total
	Rotation	Non - Rotation	
Hypersthenic	3% (6)	2% (4)	5% (10)
Sthenic	28% (56)	22% (44)	50%(100)
Hyposthenic	10.5% (21)	24.5% (49)	35% (70)
Asthenic	7.5% (15)	2.5% (5)	10% (20)
Total	49% (98)	51% (102)	100% (200)

All the categories of the body habitus showed statistically significant effects on rotation patterns at p<0.05, hypersthenic (Left rotation: X^2=82.325, df=12, p=0.000; right rotation: X^2=82.354, df=12, p=0.000) and Asthenic (Left rotation: X^2=

36.492, df=1, p=0.000; right rotation: X^2=35.521, df=1, p=0.000) **(Table 4).**

Table 4 Relationship between Body habitus (BH) and patterns of rotation in chest radiographs.

Categorization of Body Habitus	Patterns of Rotation					
	Left Rotation (LR)			Right Rotation (RR)		
	X^2	df	P Value	X^2	df	P Value
Hypersthenic	82.325	12	0.000	82.354	12	0.001
Sthenic	73.566	12	0.000	72.588	12	0.000
Hyposthenic	69.741	12	0.000	68.631	12	0.000
Asthenic	36.492	1	0.000	35.521	1	0.000

Out of 200 participants included in this study, males were 97 (48.5%), while females were 103 (51.5%). Of the 49% rotation cases, females were 53 (26.5%) when compared to their male counterparts, which is 45 (22.5%) **(Table 5).** The impact of gender on rotation on chest radiograph was evaluated using Chi-square (X^2) and the result revealed that there was statistically significant relationship between gender and rotation at (X^2=69.688, df=1 and p=0.000) **(Table 5).**

Table 5 Impact of gender on rotation in chest radiographs.

Gender	Rotation n(%)	Non-Rotation n(%)	Total n(%)	df	X^2	P-Value
Male	45 (22.5%)	52 (26%)	97(48.5%)	1	69.688	0.000
Female	53 (26.5%)	50(25%)	103(51.5%)			
Total	98(49%)	102 (51%)	200(1001)			

The area of predominant rotation on the chest radiograph was assessed and the result showed that out of 98 cases of rotations identified in this study, 53 (54.1%) were found to the right when compared to rotation to the left, which is 45 (45.9%). Chi-square (X^2) test was also used to evaluate the statistical significance of these patterns of rotation and the result revealed statistically significance at (X^2=156.989, df=1 and p=0.000) **(Table 6).**

Table 6 Predominant area of rotation in chest radiographs.

Rotation patterns	Frequency (n)	Percentage	X^2	df	P-Value
Rotation to Right	53	54.1	156.989	1	0
Rotation to left	45	45.9			
Total	98	100			

Discussion

On a PA chest radiographs, the heart size, trachea position, lung architectures can be accurately evaluated with a well-aligned PA chest radiograph [18]. If the patient is rotated to the left, then the heart may appear enlarged and when the patient is rotated to the right the heart size may be underestimated [9,18]. If the patient is rotated, then image interpretation may become difficult to even know if the trachea is deviated to one side by disease process [18]. Rotation encountered on chest radiograph introduced obliquity to the standard PA projection and equally changes the contours of the heart, great vessels, the hila, hemi-diaphragm, size and arc of the aorta and the relative density of the hemi-thoraces [7,9]. In this study rotations noted on the PA chest radiographs were evaluated by observing the medial clavicular heads and determining whether they are equidistant from the spinous process of the thoracic vertebrae bodies. This method adopted in this study is in keeping with method used in several literatures [19-21]. According to them, there is no rotation if the spinous process appears to lie equidistant from the medial end of each clavicle. For instance, if the spinous process is closer to the medial end of the right clavicle, the patient is rotated to the left and according to Herring [9], these relationships hold true regardless of whether the projection is in PA or AP chest radiograph. This method used to evaluate rotation on PA chest radiograph in this study was not in keeping with the methods adopted in similar studies conducted by Santosh et al. [22] and Horvath et al. [23]. Santosh et al. [22] study adopted the use of principal rib-orientation to automatically detect rotation on chest radiograph. In their study, they evaluated 4000 PA chest radiographs from different hospitals in Indiana and Montgomery County, U.S.A and constructed histogram based on rib- orientation detector. According to them, their method was able to distinguish severally rotated chest radiographs from non-rotated ones and achieved a maximum accuracy of 92% [22]. In Horvath et al. [23] study, they developed a Computer Aided Diagnosis (CAD) system for automatic evaluation of chest radiographs, and they reported that complete clavicle detection was impossible by CAD system. According to them, the medial epiphysis of the clavicle produces an almost invisible very dim shadow.

In this study, rotation on PA chest radiographs, Body Mass Index (BMI) and body habitus of the patients, and their relationships were also studied. These parameters evaluated in this study are in agreement with the recommendation by Hardy et al. [4] study. Their study was aimed to determine the impact of AP chest diameter on radiographic appearances of sagittal rotation on a PA chest radiograph, in which they discovered that the use of variation in distance between medial ends of clavicles and spinous process line alone without considering the individual body morphology as a measure of rotated, was flawed.

Majority of the participants included in this study have BMI of 18.50-24.50 kg/m^2 (Normal weight) and the least were those with BMI<18.50 kg/m^2. This is contrary to expectation, as the study population consisted of more of females than their male counterparts, in which one would have expected obese participants to be highest. There were statistically significant relationships between all the categories of BMI and (left and right rotations) in this study. This means that an increment in the various categories of BMI is associated with increment with right and left rotation respectively. This is in agreement with the finding documented in a study conducted by Larson et al. to examine the influence of BMI on the performance of radiograph readers when classifying localized pleural thickening. Their result showed that the proportion of false positive reading correlated with BMI, which means that the probability of false positive results increases with increased BMI. They also advised that caution should be taken when assessing chest radiographs of young obese persons.

In this study, participants with sthenic body habitus type were highest and the least were those with hypersthenic body habitus type. This finding and classification of participants in this study is in keeping with the historical classification of humans into different somatotype; such as normosthenic, muscular and athletic, hypersthenic, asthenic, talk and thin [24,25]. The effects of large body habitus on the image quality in all medical imaging modalities, making clinical interpretation of the images cumbersome has been emphasized by Rajapakse and Chang [14]. These effects could result from the rotation of the patient during image acquisition process as a result of their body habitus. According to Cramberry [26], Sthenic type of body habitus accounts for 50% of the total population of human race, followed by hyposthenic and the least hypersthenic body habitus. All the categories of body habitus showed statistically significant relationships between right and left rotations. This means that an increment in the various categories of body habitus is associated with increment with right and left rotation respectively. These observations reported by Hardly et al. [4] in their study, which investigated sagittal rotation on PA chest radiographs and the effect of body morphology on radiographic appearance in a population of 60 CT scan of thoracic. According to Hardy et al. [4], both variation in distance between medial ends of clavicles and spinous process should be considered alongside with the subject body morphology to accurately determine rotation on the chest radiographs.

There was statistically significant relationship between gender and the rotations identified in this study and greater numbers of rotation cases were females. Female preponderance noted in this study could be ascribed to the body morphology of the female subjects when compared to their male counters. In Nigeria, females were recorded to be highly obese than males [27]. Non-rotation was highest when compared to the rotation cases noted on the radiographs. This could be attributed to the fact that the chest x-ray examinations were carried out an experienced radiographer. In addition, rotation to the right was the most common pattern of rotation when compared to rotation to the left. The mechanism behind this was not captured in this study, as it is beyond the scope of this study.

Conclusion

Body morphology affects rotation on chest radiographs. Based on this study, we concluded that increment in BMI and body habitus are associated with increment in rotation on chest radiographs. Rotation on chest radiographs is more frequent in females. BMI, body habitus and female gender should be considered when assessing a radiograph with rotation.

Conflict of Interest

None declared.

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