Original Article

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Anatomy Section

A Radiological Study Emphasizing the Need to Standardise the Calcaneal Angles of Bohler and Gissane According to the Individual's Anthropological Parameters

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ABSTRACT

Introduction: The calcaneus is the largest tarsal bone, situated below and behind the talus forming a support to the ankle joint and most commonly injured bone during any fall on the foot. The Bohler's and Gissane's angles of the calcaneum play a vital role in Calcaneal fracture reduction.

Aim: The measure Bohler's and Gissane's angles of the calcaneum and correlating the same with anthropological parameters like height, weight, Body Mass Index (BMI), age and sex.

Materials and Methods: This analytical study was done in MS Ramaiah Medical College, Bangalore, Karnataka, India. The Bohler's and Gissanes angles were measured using computed Radiographs. The anthropological parameters of the patient were measured after obtaining consent. The parameters were correlated and stastically analysed using SPSS software.

Results: It was found that there is a statistically significant variation in the Bohler's and Gissane's angles with height, weight and BMI. It was observed that as the height of the individual increased the Bohler's angle increased showing a positive correlation with a p-value of 0.015. As the weight of the individual increased the Bohler's angle significantly decreased showing a negative correlation with p-value of 0.010. As weight increased the Gissane's angle widened/increased showing a positive correlation with p-value 0.013. As the BMI increased, the mean Bohler's angle decreased showing a negative correlation with p-value <0.001. There were no significant changes in the angles with age or sex of the subjects.

Conclusion: Bohler's and Gissane's angles of the calcaneum changes with the anatomical framework of a person. Hence surgical repair of Calcaneal fractures should be individualised for better postopertive results.

Keywords: Ankle, Bones, Fractures

INTRODUCTION

Calcaneus is the largest tarsal bone, it is designed to support the body and endure great degree of pressure [1]. Any injury to the foot that alters these bones, joints, soft tissues, and their relationships to one another can have a devastating impact on the ability to use the entire lower extremity, regardless of the condition of the ipsilateral hip, knee or surrounding structures. One of the key bones supporting the body weight is the calcaneus. Calcaneus is one of the commonly fractured tarsal bone, 2% of all foot fractures is accounted to the calcaneal bone [1].

Bohler's and Gissane's angles are subtended by the talar articular facet of the calcaneal bone. The Bohler's angle otherwise known as Calcaneal angle or Salient angle or Tuber joint angle is subtended at the intersection of two lines, one drawn between the highest point in the posterior talar facet to the posterior superior aspect of calcaneal tuberosity and the other line drawn to the anterior process of the calcaneus. It normally ranges from 20° to 40° [2,3]. Fracture through the calcaneus with displacement or developmental dysmorphology can cause reduction of angle to less than 28° [2].

Gissane's angle or Critical angle of Gissane is the angle subtended between lines drawn tangential to the anterior and posterior talar facets of the calcaneus. The normal angle is 130° to 145° [3].

The objective of this study was to look for any variation in the above mentioned angles with age, sex, height, weight and BMI of the individual. This study also urges the importance of individualizing the calcaneal angles according the morphometry of the individual.

MATERIALS AND METHODS

This was an analytical study, conducted by Department of Anatomy in collaboration with Department of Radiodiagnosis in MS Ramaiah Medical College, Bangalore, Karnataka, India, from September 2011 to May 2014. The study was done on South Indian population. A total of 184 ankle X-rays of 92 subjects were studied, of which 59 were male and 33 were female subjects, all more than the age of 17 years. The sample size was calculated from previous studies and it was 84, with alpha error of 5% [4]. Power (1-beta) % of the study was 80. Approval from ethical committee was obtained. The subjects were chosen randomly amongst the patients coming to the radiology department for ankle X-rays, the details of the study was explained and their consent was taken. Their age and gender were noted, their height and weight were measured using a measuring tape and an electronic weighing scale respectively. The BMI was then calculated (BMI = Weight in Kg/Square of Height in Metres) [5]. Subjects with congenital ankle anomalies or known fractures of ankle bones were excluded.

X-ray of lateral view of ankle was taken and the digital radiograph was analysed. X-rays with fractured calcaneum was excluded from the study.

The measurements of Bohler's and Gissane's angles were made using the software Dicom Viewer [Table/Fig-1,2]. The observations of Bohler's and Gissane's angles and the demographic parameters were tabulated and the correlation of the angles was statistically analysed and interpreted. The Excel and SPSS 21.0 bites version (SPSS Inc, Chicago) software packages were used for data entry and analysis. For data analysis student's t-test and analysis of variance was used, and a p-value of less than 0.05 was considered

as statistically significant. The results were presented in numbers and percentages for categorical data and averaged (mean+standard deviation) for continuous data and are presented as Tables/Figures.

[Table/Fig-1]: Lateral radiograph of ankle showing measurement of Bohler's angle.

[Table/Fig-2]: Lateral radiograph of ankle showing measurement of Gissane's angle.

RESULTS

In this study the Bohler's angles and Gissane's angles of the right and left sides of the same individual were compared and found to have no significant difference (A p-value of 0.444 for Bholer's angle and 0.211 for Gissane's angle was obtained).

In this study the population was divided into three groups based on the weight and the Bohler's and Gissane's angles were analysed between these groups [Table/Fig-3]. On analysis using one-way analysis of variance, it was found to be a statistically significant relation between the angles in the three groups. As the weight increased the Bohler's angle significantly decreased (showing a negative correlation). On the other hand as weight increased the Gissane's angle widened/increased (showing a positive correlation).

	Weight (in kg)	N	Mean (in degrees)	SD	Min.	Max.	'F' value	p-value
Mean Gissane's Angle	41-60	32	105.59	8.90	93.0	125.5	4.559	0.013*
	61-80	54	109.06	12.11	86.9	136.1		
	81-100	6	120.03	8.56	108.2	133.6		
	Total	92	108.57	11.33	86.9	136.1		
Mean Bohler's Angle	41-60	32	32.60	4.75	22.0	44.8	4.869	0.010*
	61-80	54	31.12	4.62	19.6	41.7		
	81-100	6	26.30	3.23	23.8	32.4		
	Total	92	31.32	4.79	19.6	44.8		

[Table/Fig-3]: Correlation of the mean of Bohler's and Gissane's angles of the calcaneus according to the weight.
Statistical tests: Analysis of variance. *p<0.05 hence it is statistically significant

The population was divided into four groups based in the WHO definition for BMI as underweight, normal, pre-obese and obese and the Bohler's and the Gissane's angles were measured in each group and compared [Table/Fig-4,5] [5]. By using one-way analysis of variance, it was noted that as the BMI increased, the mean Bohler's angle decreased.

Similarly the population was divided into three categories based on height and the Bohler's and Gissane's angles were studied [Table/Fig-6]. It was observed that as the height increased the Bohler's angle increased. This correlation was also found to be statistically significant. However, there was no such a significant correlation in the Gissane's angle.

	BMI (Kg/m^2)	N	Mean (in degrees)	SD	Min.	Max.	'F' value	p-value
Mean Gissane's Angle	Underweight (<18.5)	9	107.62	9.72	95.1	118.3	1.215	0.309
	Normal (18.50-24.99)	40	106.80	9.51	93.0	126.9		
	Pre-obese (25.0-29.99)	33	109.26	13.35	86.9	136.1		
	Obese (≥30.00)	10	114.19	11.69	94.9	133.6		
	Total	92	108.57	11.33	86.9	136.1		

[Table/Fig-4]: Correlation of the mean of Gissane's angle of the calcaneus based on BMI.
Statistical tests: Analysis of variance.

	BMI (Kg/m^2)	N	Mean (in degree)	SD	Min	Max	'F' value	p-value
Mean Bohler's Angle	Underweight (<18.5)	9	35.24	5.73	27.5	44.8	8.098	<0.001*
	Normal (18.50-24.99)	40	31.86	4.39	22.0	41.7		
	Pre-obese (25.0-29.99)	33	31.26	3.98	19.6	40.3		
	Obese (>=30.00)	10	25.84	3.57	20.8	31.8		
	Total	92	31.32	4.79	19.6	44.8		

[Table/Fig-5]: Correlation of the mean of Bohler's angle of the calcaneus based on BMI.
Statistical tests: Analysis of variance *p<0.05 hence, it is statistically significant

Correlation of Bohler's and Gissane's angle of calcaneum with age and gender of the individual using one-way analysis of variance did not show any statistically significant variation [Table/Fig-7-9].

	Height (in cm)	N	Mean (in degrees)	SD	Min.	Max.	'F' value	p-value
Mean Gissane's Angle	144-153	4	104.01	12.26	94.9	121.9	0.440	0.646
	154-163	33	108.05	12.09	86.9	133.1		
	164-173	55	109.21	10.92	90.9	136.1		
	Total	92	108.57	11.33	86.9	136.1		
Mean Bohler's Angle	144-153	4	24.98	5.78	19.6	31.8	4.373	0.015*
	154-163	33	31.02	4.15	21.7	38.0		
	164-173	55	31.97	4.81	22.0	44.8		
	Total	92	31.32	4.79	19.6	44.8		

[Table/Fig-6]: Correlation of the mean of Bohler's and Gissane's angles of the calcaneus according to the height.
Statistical analysis: one-way analysis of variance *p<0.05 hence, it is statistically significant

DISCUSSION

The study population was divided into six groups based on age and the Bohler's and Gissane's angles were compared. There was no significant relation between the angles with regards to age. Various other studies done in the American, Nigerian, Saudi, Turkish population concluded the same [4,6-9].

In the present study, there was no significant variation in Bohler's and Gissane's angles of males as compared to females unlike the

		N	Mean (in degrees)	SD	Min.	Max.	't' value	p-value
Gissane's Angle	Male	59	109.19	11.06	90.6	137.8	0.590	0.444
	Female	33	107.27	12.16	87.5	134.5		
	Total	92	108.50	11.43	87.5	137.8		
Bohler's Angle	Male	59	31.83	5.09	21.2	46.2	1.589	0.211
	Female	33	30.44	5.07	18.7	38.1		
	Total	92	31.33	5.10	18.7	46.2		

[Table/Fig-7]: Correlation of mean Bohler's and Gissane's angles of the calcaneus according to the gender.
Statistical tests: Student t-test

	Age (years)	N	Mean (in degrees)	SD	Min	Max	'F' value	p-value
Mean Bohler's Angle	18-20	4	36.88	2.86	35.0	41.1	1.789	0.124
	20-29	13	31.04	4.07	25.0	39.1		
	30-39	19	29.65	3.29	23.3	37.0		
	40-49	22	30.98	4.67	21.7	41.7		
	50-59	13	31.53	5.85	19.6	40.3		
	≥60	21	32.19	5.49	20.8	44.8		
	Total	92	31.32	4.79	19.6	44.8		

[Table/Fig-8]: Correlation between mean Bohler's angles in different age groups.
Statistical tests: one-way analysis of variance

	Age (years)	N	Mean (in degrees)	SD	Min.	Max.	'F' value	p-value
Mean Gissane's Angle	18-20	4	113.35	8.275	102.1	121.8	0.513	0.766
	20-29	13	111.50	10.34	98.9	133.6		
	30-39	19	106.05	10.61	90.9	124.6		
	40-49	22	108.59	12.37	86.9	136.1		
	50-59	13	109.02	11.94	95.8	133.1		
	≥60	21	107.81	12.05	91.4	128.4		
	Total	92	108.57	11.33	86.9	136.1		

[Table/Fig-9]: Correlation between mean Gissane's angles in different age groups.
Statistical tests: one-way analysis of variance

study done in Ugandan population which concluded that females have greater Bohler's angle than males [10].

In this study as the weight increased the Bohler's angle significantly decreased. On the other hand, as weight increased the Gissane's angle widened/increased. Similar correlation was noted with BMI. A similar study was conducted by Shoukry FA et al., in the Egyptian population in which the Bohler's angle's and Gissane's angle was compared by dividing the population according to the WHO classification of BMI. Their results also suggested that with an increase in BMI the Bohler's angle decreased. But this was not statistically approved [11].

Fractures of calcaneum account for nearly 60% of all tarsal injuries. A 10% of calcaneal fractures are bilateral. A 70-75% of fractures are of the intra-articular type and about 2% are compound fractures [12].

Calcaneal fractures are prevalent amongst middle-age people and most of these injuries require long term rehabilitation before the patient returns to work. So such fractures carry a burden in the socio-economic life of the individual. In Netherlands it has been estimated that the annual expenses on displaced intra-articular calcaneal fractures are 20.5 to 30.7 million Euros [13]. Hence, it is vital that these fractures are precisely diagnosed and meticulously treated.

The Bohler's angle measured in an X-ray at the time of trauma guides the treatment [7]. A decrease in the Bohler's angle to less than 28 degree or an increase in Gissane's angle to more than 140 degrees signifies a calcaneal fracture, although, a normal Bohler's angle does not exclude calcaneal fracture. Literature affirms that the measurement of Bohler's angle and Gissane's angle also serves as a guide in assessing outcome following surgical or non surgical treatment of calcaneal fractures [14-17]. Hence Bohler's angle plays a pivotal role in the diagnosis, treatment and prognosis of calcaneal fractures.

From this study, it is evident that the range of Bohler and Gissane's angle vary with parameters like weight, height and BMI which alter weight bearing on the lower limb. Hence, during the radiological diagnosis or surgical reduction of fractured calcaneus the measurements of angles when applied appropriately according to the weight, height or BMI of the individual yield best results. This study can be further extended by standardising the angles for ranges of weight, height and BMI.

LIMITATION

The study could have been extended to various other races and the Bohler's and Gissanes's angles can be calculated and standardised to those populations. This study can also be extended to subjects around the country for the values and can be standardised. The sample size in this study was not sufficient for standardization of the angles.

CONCLUSION

Bohler's and Gissane's angles are fundamental in making accurate diagnosis, decision making in treatment, surgical procedure and in evaluation of prognosis in patients with calcaneal fractures. From the study, it can be concluded that the Bohler's angle decreases with increasing ranges of weight and BMI. Bohler's angle increases with increasing height. The Gissane's angle increased with the increasing weight and BMI. This urges the need to standardise the Bohler's and Gissane's angles of the calcaneum according to the individual's anthropometric parameters by extending the study furthermore in various groups of population and other races.

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