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Role Of Ultrasound Imaging in Assessment of Growth Plate and Its Clinical Applications – A One Year Hospital Based Observational Study

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ABSTRACT

Introduction: The cartilaginous primary physis or growth plate is a critical component of the immature skeleton and is present at the end of long bones in children allowing for longitudinal bone growth. Plain radiography is currently the standard imaging choice for fractures in children but isolated physeal fractures are easily missed on radiographs making Ultrasound a potential modality in detecting such fractures. **Objectives:**1)To determine baseline measurements of physeal plate width and to assess variation in the measured widths among contralateral sides, age group and sex in the pediatric population. 2)Ultrasound assessment of physeal plate in normal uninjured children in order to detect any variations from the normal anatomy if present including physeal plate fracture, bridge and premature closure of the physis. **Methodology**: This is a hospital based observational study, conducted for a period of 1 year in children between 5 to 12 years referred for ultrasound imaging to the department of Radio-diagnosis, KLE'S Dr Prabhakar Kore Hospital. A total of 96 patients were included in this study. Children were subjected to B-Mode ultrasonography of distal end of long bones- radius, ulna, tibia and fibula using a 7.5–12 MHz high frequency linear array transducer on GE VOLUSON machine (GE Healthcare, USA) and Philips HD-11Xe machine. **Results:** No significant statistical difference could be elicitated in physeal plate width measurement in children of different gender and similar age group. The average physeal plate width found in distal end of fibula is 3.0 ± 0.22 mm with a mean difference of 0.11 ± 0.3 mm between contralateral sides. For tibia is 3.5 ± 0.28 mm with a mean difference of 0.1 0.31mm between contralateral sides. For radius is 2.88 ± 0.25 mm with a mean difference of 0.08 ± 0.31mm between contralateral sides. for ulna is

2.74 ± 0.24 mm with a mean difference of 0.1 ± 0.32 mm between contralateral sides. No statistical difference was found in the physeal plate width between the contralateral sides for the long bones which were imaged in the study - radius, ulna, fibula or tibia. **Conclusion**: This study demonstrates that there is no statistically significant difference in physeal plate widths between contralateral extremities and between the two genders and age. The sonographic detection of significant disparities in physeal plate widths of injured children may have the potential for earlier detection of SH injuries with subsequent appropriate management.

Keywords: *Long bones, Physeal plate width, Ultrasonography*

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1. INTRODUCTION

Skeletal fractures exhibit unique patterns in the pediatric population because of the properties of growing bone [(1)], including longitudinal and radial growth of the bone, which occurs during childhood and adolescence [(2)].

Present at the end of long bones between the metaphysis and epiphysis, the cartilaginous primary physis or growth plate is the most critical component of the immature skeleton. It allows for longitudinal bone growth [(1)] but is also the weakest skeletal structure in children[(3)]. Injury to either the growth plate (direct injury) or the adjacent epiphysis and metaphysis (indirect injury) can cause growth plate dysfunction, ultimately leading to growth disturbances. The most common insult mechanism is trauma, which can directly or indirectly injure the growth plate.[(4)] Approximately eighteen percent of all fractures in children involve the growth plate and 5% to 10% of physeal fractures lead to growth disturbances [(5)].

Less common mechanisms of indirect causes of injury include vascular compromise, infection, inflammation, radiation and tumour. The most often-described growth disturbance is premature physeal closure with bone bridge formation [(4)]. Chronic repetitive physeal injuries can also cause physeal widening or physeal bridges [(6)].

The Salter-Harris classification system is currently used to grade the fractures involving the growth plate in children [(7)]. The physeal fractures are subdivided into five classes based on their radiographic appearance and causal mechanism [(4)]

Type I Salter-Harris fractures, accounting for 6.0%–8.5% of growth plate fractures, are transverse cleavages through the growth plate [(4)]. The physeal fractures account for 21 % to 30% of all long bone injuries.[(1)] Also, there is a greater propensity for growth disturbance when injuries occur at the distal ends compared to the proximal ends of the long bones [(8)].

Plain radiography is currently the standard imaging choice for fractures in children, but isolated physeal fractures, i.e. Salter-Harris type I fracture are easily missed on radiographs. Due to the lack of any prominent radiographic signs on initial presentation, the diagnosis of an undisplaced Salter-Harris type I injury becomes more of a clinical diagnosis based on swelling and tenderness directly over the affected physis of long bones [(9)]

Ultrasound thereby has a potential role in detecting such fractures and in the prevention of future growth disturbances. It has the advantage of real-time assessment, ease of access, and cost-effectiveness with no radiation exposure at all, making it a superior and more convenient modality to use in paediatric emergencies and in follow-up cases where the use of radiography leads to repeated radiation exposure.

However, there are no established sonographic criteria for normative baseline measurements for pediatric physeal plate widths, making identification and diagnosis of SH-I fractures challenging and subjective.

OBJECTIVES:

1. To determine baseline measurements of physeal plate width and to assess variation in the measured widths among contralateral sides, age group, and sex in the pediatric population.
2. Ultrasound assessment of physeal plate in normal uninjured children in order to detect any variations from the normal anatomy if present including physeal plate fracture, bridge and premature closure of the physis

2. MATERIAL AND METHODS

Source of data: Children between the age group of 5-12years referred for Ultrasound imaging to the Department of Radio-Diagnosis at The KLE'S Dr. Prabhakar Kore hospital & MRC, Belgaum.

Method of collection of data:

(a) Study design: Hospital based observational study

(b) Sample size: Study comprised of 96 patients.

(c) Sample size formula:

The minimum sample size formula based on prevalence rate:

where P is the percentage of prevalence and d is the percentage likely difference in the prevalence.

Z is linked with z_α is linked with the level of significance. For 5% level of the significance $z_\alpha = 1.96$.

$$n = \frac{Z^2 p(1-p)}{d^2}$$

With P = 40% and d = 25% of P = 10.0%, the minimum sample size is 92.

(d) Study duration: January 2021-December 2021

(e) Sampling method: Non probability purposive sampling

(f) Inclusion criteria:

1) Any child between the age group of 5–12 years referred to the Department of Radio-diagnosis at The KLE'S Dr. Prabhakar Kore hospital & MRC for ultrasound imaging.

(g) Exclusion criteria:

1) Any child having some known bony deformity.

2) Any child below the age of 12 years presenting with premature physeal closure.

3) Parental refusal of participation.

(h) Methodology:

Data was collected in patients referred for ultrasound imaging to the Department of Radio-Diagnosis at the KLE's Dr. Prabhakar Kore Hospital & MRC, Belagavi.

An informed verbal assent from children aged 7-12 years and written consent from the parents of all the subjects was obtained.

A pre-structured proforma was used for the collection of clinical data.

The above mentioned study population who met the inclusion criteria and did not get excluded were subjected to ultrasound of distal end of long bones on both sides mainly– radius, ulna, tibia and fibula. In a total of 96 children, the assessment of growth plate physeal width measurement was done on both sides using linear array transducer of 7.5-12 MHz on GE VOLUSON machine (GE Healthcare, USA) and Philips HD-11Xe. The transducer was placed along the long axis of ankle and wrist. After visualizing the metaphysis, the transducer was further slid distally to visualize the physeal plate which was seen as a smooth space between the epiphysis and metaphysis. To assess the physeal plate width, the measurement were taken on the dorsal surface of wrists, medial surface of tibia and lateral surface of fibula

on both sides. All the children were examined on real-time two-dimensional greyscale and the images were stored securely.

Assessment of normal physeal plate with baseline measurements of physeal plate width along with assessment of variation in the measured widths among contralateral sides, age group, and sex in the study subjects were done.

Follow up: No

Ethical considerations: This research was accepted by an institutional human ethics committee. All research participants received informed written consent and only those participants willing to sign the informed consent were included in the research. The confidentiality of the participants in this research was preserved.

The data gathered was analyzed and presented where possible in the form of tables, graphs, figures, and diagrams.

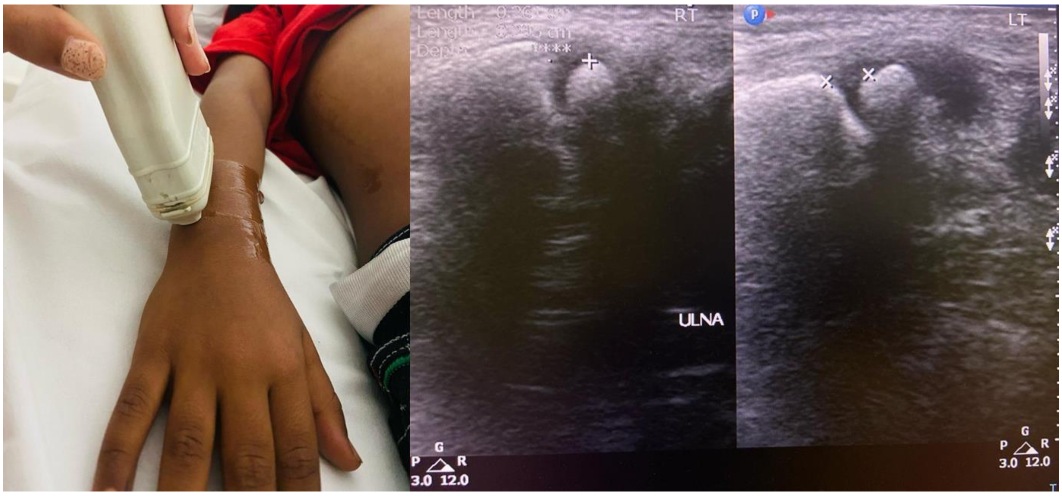

Fig.1 Clinical image of position of the transducer over dorsal aspect of the wrist on ulnar side . Ultrasound image shows measurement of width of ulnar physeal plate.

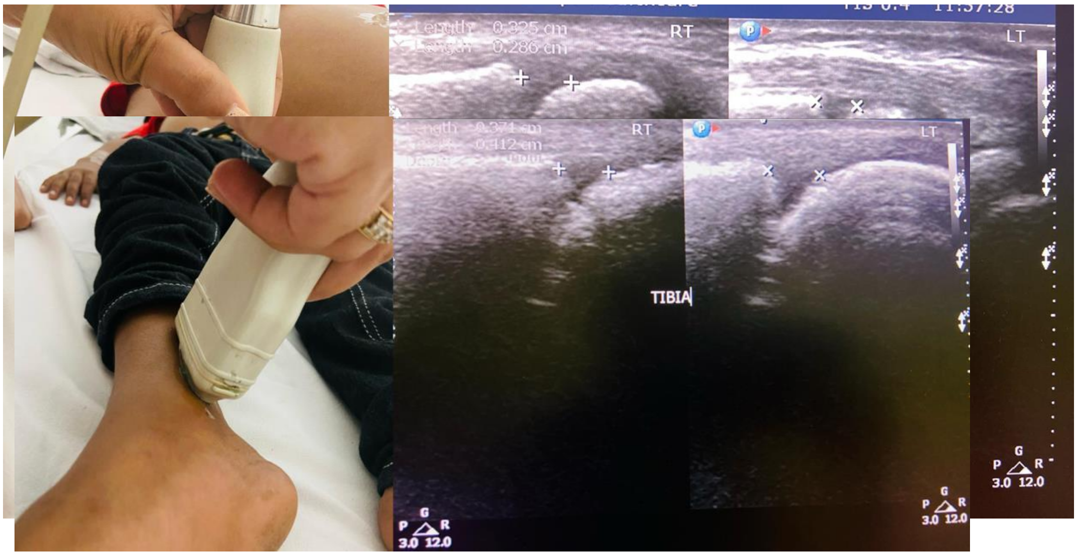

Fig.2 Clinical image of position of the transducer over dorsal aspect of the wrist on radial side . Ultrasound image shows measurement of width of radial physeal plate.

Fig.3 Clinical image of position of the transducer over medial surface of tibia . Ultrasound image shows measurement of width of tibial physeal plate.

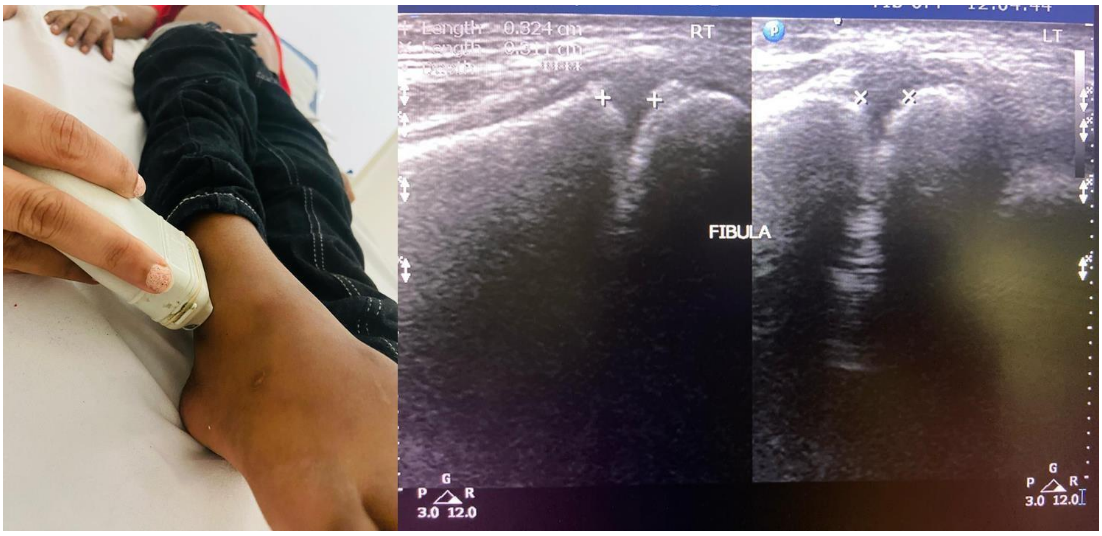

Fig.4 Clinical image of position of the transducer over lateral surface of fibula . Ultrasound image shows measurement of width of fibular physeal plate.

STATISTICAL METHODS :

Descriptive analysis was carried out by mean and standard deviation for quantitative variables, frequency, and proportion for categorical variables. Non normally distributed quantitative variables were summarized by median and interquartile range (IQR). Data was also represented using appropriate diagrams like bar diagram, pie diagram and box plots.

All Quantitative variables were checked for normal distribution within each category of explanatory variable by using visual inspection of histograms and normality Q-Q plots. Shapiro- wilk test was also conducted to assess normal distribution. Shapiro wilk test p value of >0.05 was considered as normal distribution.

For normally distributed Quantitative parameters the mean values were compared between study groups using independent sample t-test (2 groups)

P value < 0.05 was considered statistically significant. IBM SPSS version 22 was used for statistical analysis.
IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp

3. RESULTS

Table 1: Descriptive analysis of age in study population (N=96)

Parameter	Mean ± SD	Median	Minimum	Maximum	95% C.I	
					Lower	Upper
Age	8.25 ± 2.17	8.00	5.00	12.00	7.81	8.69

The study had subjects between the age group 5 to 12 years. The average age of the population was 8.25 years in this study**.**

Table 2: Descriptive analysis of age group in the study population (N=96)

Age Group	Frequency	Percentages
5-8	56	58.33%
9-12	40	41.67%

The enrolled subjects were further grouped into two age groups and it was noticed that 58% of the study population were between the age of 5-8 years and almost 42% were between 9-12 years old.

Table 3: Descriptive analysis of gender in the study population (N=96)

Gender	Frequency	Percentages
Male	54	56.25%
Female	42	43.75%

Out of the 96 study subjects enrolled in the study, 54 were male and 42 were females.

Table 4: Descriptive analysis of physeal plate width in study population Total (N= 96)

Parameter	Mean ± SD	Median	Minimum	Maximum	95% C.I	
					Lower	Upper
Physeal Plate Widths (mm)						
Right Radius	2.88 ± 0.25	2.9	2.3	3.5	2.8	2.9
Left Radius	2.96 ± 0.27	2.9	2.4	3.5	2.9	3.0
Right Ulna	2.74 ± 0.24	2.8	2.2	3.4	2.7	2.8
Left Ulna	2.84 ± 0.27	2.9	2.1	3.3	2.8	2.9
Right Fibula	3.0 ± 0.22	3.0	2.6	3.6	3.0	3.1
Left Fibula	3.11 ± 0.25	3.1	2.5	3.7	3.1	3.2
Right Tibia	3.5 ± 0.28	3.5	2.8	4.2	3.5	3.6
Left Tibia	3.6 ± 0.31	3.6	2.5	4.2	3.5	3.7

Difference Between Contralateral Side						
Radius	-0.08 ± 0.31	-0.1	-0.6	0.5	-0.1	0.0
Ulna	-0.1 ± 0.32	-0.2	-0.6	0.7	-0.2	0.0
Fibula	-0.11 ± 0.3	-0.2	-0.6	0.5	-0.2	0.0
Tibia	-0.1 ± 0.31	-0.2	-0.6	0.6	-0.2	0.0

The above table establishes that there is no statistical difference in the physeal plate width between the contralateral sides for all the long bones which were imaged in the study - radius, ulna, fibula or tibia.

The median value of physeal plate in right and left radius was same (2.9) whereas there was a difference of 0.1 while comparing the physeal plates of ulna (2.8 right and 2.9 left), fibula (3.0 right and 3.1 left) and tibia (3.5 on the right and 3.6 on the left).

Table 5: Comparison of mean of physeal plate width between age group (For Male) (N=54)

Parameter	**Age Group (Mean± SD)**	
	5-8 Years (N=33)	**9-12 Years (N=21)**
Physeal Plate Widths (mm)		
Right Radius	2.87 ± 0.28	2.91 ± 0.19
Left Radius	2.98 ± 0.27	3.03 ± 0.3
Right Ulna	2.75 ± 0.27	2.79 ± 0.16
Left Ulna	2.88 ± 0.22	2.9 ± 0.28
Right Fibula	2.99 ± 0.2	3 ± 0.17
Left Fibula	3.1 ± 0.23	3.14 ± 0.25
Right Tibia	3.47 ± 0.26	3.45 ± 0.28
Left Tibia	3.56 ± 0.32	3.55 ± 0.35
Difference Between Contralateral Side		
Radius	-0.11 ± 0.32	-0.12 ± 0.31
Ulna	-0.12 ± 0.35	-0.12 ± 0.32
Fibula	-0.11 ± 0.3	-0.14 ± 0.31
Tibia	-0.09 ± 0.31	-0.1 ± 0.33

The above table compares the differences in the mean width of contralateral physeal plate of the radius, ulna, fibula and tibia in the two age groups comprising of only males while proving there is no significant statistical difference seen in the two age groups.

Table 6: Comparison of mean of physeal plate widths between age group (For Female) (N=42)

Parameter	Age Group (Mean± SD)	
	5-8 Years (N=23)	9-12 Years (N=19)
Physeal Plate Widths (mm)		
Right Radius	2.83 ± 0.26	2.94 ± 0.25
Left Radius	2.95 ± 0.27	2.85 ± 0.23
Right Ulna	2.68 ± 0.23	2.74 ± 0.28
Left Ulna	2.77 ± 0.34	2.79 ± 0.25
Right Fibula	3.01 ± 0.23	3.02 ± 0.28
Left Fibula	3.1 ± 0.27	3.08 ± 0.27
Right Tibia	3.52 ± 0.29	3.59 ± 0.29
Left Tibia	3.62 ± 0.3	3.72 ± 0.26
Difference Between Contralateral Side		
Radius	-0.13 ± 0.3	0.09 ± 0.27
Ulna	-0.08 ± 0.35	-0.06 ± 0.25
Fibula	-0.1 ± 0.31	-0.07 ± 0.29
Tibia	-0.1 ± 0.3	-0.12 ± 0.29

The above table compares the differences in the mean width of contralateral physeal plate of the radius, ulna, fibula and tibia in the two age groups comprising of only females while proving there is no significant statistical difference seen in the two age groups.

Table 7: Descriptive analysis of any physeal plate abnormality detected in the study population (N=96)

Any Physical Plate Abnormality Detected	Frequency	Percentages
NIL	96	100.00%

Our study population comprised of healthy uninjured children and didn't show any incidental physeal plate abnormalities.

Table 8: Comparison of mean physeal plate widths and differences between the contralateral side between age group (N=96)

Parameter	Age Group (Mean± SD)		P value
	5-8 Years (N=56)	9-12 Years (N=40)	
Physeal Plate Widths (mm)			

The above table did not show any statistical difference in the measured physeal plate width and their difference between the contralateral side be it radius, ulna, fibula or tibia between the two age groups under consideration in this study

Table 9: Comparison of mean physeal plate widths and differences between the contralateral side between

gender (N=96)

Parameter	Gender (Mean± SD)		P value
	Male (N=54)	Female (N=42)	
Physeal Plate Widths (mm)			
Right Radius	2.89 ± 0.25	2.88 ± 0.26	0.872
Left Radius	3 ± 0.28	2.91 ± 0.26	0.100
Right Ulna	2.76 ± 0.23	2.71 ± 0.25	0.249
Left Ulna	2.89 ± 0.24	2.78 ± 0.3	0.051
Right Fibula	2.99 ± 0.19	3.01 ± 0.25	0.696
Left Fibula	3.12 ± 0.24	3.1 ± 0.27	0.678
Right Tibia	3.46 ± 0.27	3.55 ± 0.29	0.109
Left Tibia	3.56 ± 0.33	3.66 ± 0.28	0.094
Difference Between Contralateral Side			
Radius	-0.11 ± 0.31	-0.03 ± 0.31	0.190
Ulna	-0.12 ± 0.33	-0.07 ± 0.31	0.443
Fibula	-0.12 ± 0.3	-0.08 ± 0.3	0.531
Tibia	-0.09 ± 0.32	-0.11 ± 0.29	0.812

The above table proves that the differences in the physeal plate width and its variation between the contralateral sides in radius, ulna, tibia and fibula is statistically insignificant between the two genders.

4. DISCUSSION

Ultrasound being a non-invasive and cost-effective imaging modality can play a vital role in diagnosis of radiographically occult or isolated physeal fracture i.e., Salter-Harris type I fracture. This study conducted over a period of 12 months in the Department of Radiodiagnosis, Jawaharlal Nehru Medical College, Belagavi is thereby done with the purpose of establishing the importance of ultrasonography in diagnosis of pediatric physeal plate fractures.

In the current study, after considering the inclusion and exclusion criteria, sample size was taken as 96 being almost similar to the sample size of 95 used by Lorraine et al. (1) in his study.

In this study we tried to successfully compile a database of baseline measurements of the physeal widths of the four long bones - radius, ulna, fibula and tibia with further comparison of the width between the contralateral side, gender and age. This database would aid to detect any disparity further helping in diagnosis of physeal plate fracture.

It has been researched that a variety of pathological conditions including fractures in patients with immature skeleton may affect the physis resulting in complications like growth arrest, limb shortening, development of bone bridges and angular deformities.(10)

The study was done on healthy children between age 5 to 12 years further divided into two age groups mainly 5 to 8 years and 9 to 12 years with no history trauma or skeletal abnormality. The maximum age of the included subject was capped at 12 years in order to avoid cases with closed physeal plate.

The number of males included in the study were 54 (56.25 %) outnumbering the number of females which were 42 (43.75%).

Maximum number of children enrolled in the present study were between the age group of 5-8 years (58.33%) with a mean of 8.25 years and a standard deviation of 2.17 whereas the mean age in the study done by Lorraine et al (1) was 6 years 3 months.

Shari T et al. in his study compared three imaging modalities namely radiographs, computed tomography and magnetic resonance imaging, and found MRI to be the most sensitive of all to visualize the physis (11). However recent studies like that of Lorraine et al (1) and Crystal C Wang et al (12) stated sonography to be effective in accurately determining physeal plate width and thereby help in diagnosing physeal injuries.

Naum simanovsky et al. (13), in their study established that sonography is more sensitive in detecting fractures when compared to radiographs.

Since there is a lack of a sonography data regarding the physeal plate fractures, we chose ultrasonography as the modality to evaluate the physeal plate in our study.

Our study is the first in the nation to evaluate, measure and compare physeal plate widths among pediatric population with respect to contralateral side, gender and age.

The average physeal plate width, in our study population, found in distal end of fibula, radius, ulna and tibia have been compiled in the results along with the differences seen in contralateral sides of each.

Sonography of none of the children in the study revealed any kind of incidental physeal abnormalities or variations. Also, in our study we could not establish any statistically significant disparity in physeal plate width measurement between contralateral sides.

Lorraine et al. (1), found in their study that there was minimal variation in the physeal plate widths of pediatric patients regardless of age or sex, and the same result was seen in our study where there was very minimal variation in the widths seen in both age and sex.

Our study aids the study conducted by Lorraine et al.(1) in establishing baseline values of physeal plate width which can be used by all the radiologists to diagnose Salter Harris 1 fractures commonly missed over radiographs.

No intervention was observed in our study.

5. CONCLUSION

In this study on 96 patients, physeal plate widths of four long bones were measured and compared between contralateral sides, age and gender aiding in formulating a baseline of physeal plate width measurements that can be of use in emergency settings to diagnose fractures commonly missed over radiographs.

It can be concluded that a common baseline value for physeal plate can be used for the pediatric age group 5-12 years and in both sexes as no statistically significant difference was observed between them

6. LIMITATIONS

The present study is only a single-center observational study with a relatively small sample size. To establish a baseline measurement of physeal plate width, a larger sample would give more accurate data. The study results therefore cannot be generalized because of the small sample size and single center sampling.

Future multi-centric studies with a large sample size could increase the validity of the results and can further help in generating clinical and radiological evidence for making recommendations in the day-to-day practice.

Another limitation of our study is that the ultrasound technique largely depends on the skill of the examiner and hence the data regarding physeal plate width could face intra and inter-observer variations.

Also distal ends of only four long bones were assessed in the study. Further studies including more long bones with assessment of their physeal width at both proximal and distal ends would provide a better data further helping the radiologists in cases of occult pediatric fractures

Lastly, no radiograph or MRI was performed to corroborate the findings.

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