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Original article

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Incidence of Distal Radius Fracture in Children Peaks Around the Pubertal Growth Spurt: A Hospital-Based Study Over Twelve Years (2000 to 2011)

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Abstract

Introduction: A significant asynchrony between statural growth rate and mineral mass accrual may contribute to the increased prevalence of low-energy fractures observed during puberty. This disparity is most pronounced when the compact bone of the radius exhibits a temporary surge in porosity concurrent with the most rapid phase of linear growth.

Materials & Methods: The district hospital, Sindhudurg complete medical records are used to identify all distal radius fracture younger than 18 years, treated during 2000 to 2011. The medical record linkage system of regular and periodical school health medical examination performed by medical officers tested biannually, anthropometrically, physiologically and clinically for whole district children provides the unique data on velocity of growth. This demographic data of distal radius fracture in children and adolescents are compared with, documentation of longitudinal velocity of growth of the same children that was collected during the identical time period for children from the same student population of Sindhudurg.

Results: After adjusting for age and sex, the annual incidence rates per 100,000 population showed a statistically significant increase from 2.8 (95% CI 2.4-3.3) in 2000, to 6.3 (95% CI 5.7-6.9) in 2006, and 12.7 (95% CI 11.9-13.4) in 2011. The average age for peak growth velocity was 14.2 years in boys and 12.6 years in girls, according to the Government of Maharashtra's school health program. Notably, the incidence of fractures peaked at ages 13.1 to 15.2 in boys and 11.4 to 13.8 in girls.

Conclusion: The long term data for whole Sindhudurg district indicates a correlation between the peak incidence of distal radius fractures and the age of maximum growth velocity in both boys and girls, suggesting a potential vulnerability during this critical growth phase.

Keywords: Distal radius fracture in children, Adolescent, Puberty, Growth spurt, Longitudinal velocity of growth.

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Introduction

Adolescence is a pivotal stage marked by heightened physical activity, which plays a crucial role in optimizing skeletal mass [1]. However, the intricate dynamics between bone density, size, mass, and mineral content in adolescents remains elusive [2]. The scientific community is divided, with some researchers advocating that bone density peaks during adolescence due to increased trabecular bone density [3]. Conversely, other studies argue that low bone density is an unlikely factor in adolescent fractures [4]. The variability in bone mineral density throughout childhood and adolescence is widely acknowledged [5].

Moreover, there is a discourse on the transient imbalance between physical activity levels and bone mass accrual during puberty [6]. Certain studies highlight a dissociation between linear skeletal growth and bone mineralization in this age group [7]. It is theorized that the developing skeleton, coupled with ongoing

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Table 1: Age specific incidence rates in boys of distal radius fracture between 2000 to 2011

Age in Years	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	0	0	0	0	0	0	1	0	1	1	1	0
2	0	0	0	0	1	1	2	1	0	0	1	0
3	0	1	1	2	0	1	0	0	1	1	0	1
4	1	0	0	1	0	0	1	1	0	1	1	0
5	0	0	1	0	1	2	1	0	0	1	0	1
6	0	1	0	0	0	1	2	1	1	0	0	1
7	1	0	0	1	1	0	0	1	0	1	1	1
8	1	0	1	0	0	0	1	1	1	0	1	0
9	0	0	0	1	0	0	0	0	1	0	1	1
10	0	1	0	0	1	0	2	1	1	0	0	0
11	1	2	1	1	0	1	1	0	0	1	0	1
12	0	2	1	0	1	2	2	2	2	3	1	1
13	2	2	4	3	4	5	6	7	8	10	13	15
14	4	5	4	4	5	8	7	8	10	16	21	23
15	3	2	3	3	3	3	6	6	9	14	16	21
16	1	0	1	0	1	0	0	1	1	2	2	2
17	0	1	0	1	1	0	0	2	1	2	3	2
18	0	0	1	1	0	0	1	2	1	1	0	1
Total	14	17	18	18	19	24	33	34	38	54	62	71

mineralization, may contribute to a transient reduction in cortical bone mass, leading to a thinner cortex at the radius metaphysis. This condition is often accompanied by a temporary surge in cortical porosity due to increased bone turnover [8].

The aim of this investigation is to assess the prevalence of distal radius fractures in the paediatric and adolescent population of Sindhudurg, located along Maharashtra's western coastline, from 2000 to 2011. Additionally, this study seeks to examine any temporal shifts in fracture incidence. To achieve this, fracture demographic data will be juxtaposed with the longitudinal growth velocity records of the same demographic cohort in Sindhudurg during the corresponding time frame.

Materials and Methods

We compiled medical records from all school health teams in Sindhudurg to identify cases of distal radius fractures in individuals under 18 years, spanning from 2000 to 2011. The data collection process was comprehensive, involving cross-verification of outpatient and inpatient records with corresponding X-ray and operation theatre registers, ensuring a complete and consistent dataset over time.

The author was District Civil Surgeon of Sindhudurg during the study period, with the ability to review the medical records of 686 children with distal radius fractures and access the district's school health examination program records.

Geographically, Sindhudurg is the southernmost district of Maharashtra, bordered by Karnataka and Goa. Patients from these neighbouring states treated at the district hospital but not residing in Sindhudurg were excluded from the study. The hospital's inpatient register captured more severe cases of distal radius fractures, while the outpatient register recorded less severe, simple, and un-displaced fractures treated with plaster casts without the need for hospitalization. This approach ensured comprehensive coverage of Sindhudurg's population, given that the Government district hospital was the sole provider of orthopaedic services, accurately reflecting fracture incidence trends among the youth.

The Maharashtra state school health examination program, Rastriya Bal Swasthya Karyakram, operated under the supervision of the District Civil Surgeon, caters to children from anganwadis (rural child care centres), pre-primary, primary, secondary, and high schools, covering ages 0 to 18 years [9]. Twelve medical teams conducted biannual health examinations throughout the district, on fixed day, fixed time and fixed school with advanced tour programme. Each team comprised medical officers, nurses, a statistician, a pharmacist, and data entry operators, equipped with transportation vehicle for scheduled visits. Monthly reports from each team were submitted to the District Civil Surgeon, culminating in an annual consolidated report. The continuity of medical staff over the twelve-year period minimized variability in the examinations.

This longitudinal study also included detailed anthropometric measurements of height and weight, taken semiannually to monitor growth and maturation. Height measurements were taken without shoes using a wall stadiometer, following a free-standing technique with the head in the mid-sagittal plane, accurate to 0.1 cm. The study evaluated the relationship between serial height measurements and peak growth velocity, allowing for comparison across a common maturational landmark—the age of peak growth velocity. This method effectively accounted for the wide range of maturational differences in boys and girls of the same chronological age. The study cohort consisted of 402 boys (58.6%) and 284 girls (41.4%), who, after twelve years, provided sufficient longitudinal data to construct mathematically defined growth curves and determine the age at which peak height velocity occurred [10].

Table 2: Age specific incidence rates in girls of distal radius fracture between 2000 to 2011

Age in years	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	0	0	1	0	0	0	1	0	0	1	1	0
2	0	0	0	0	0	1	0	2	0	0	0	0
3	0	0	0	0	0	1	0	0	0	1	0	1
4	0	0	0	0	0	0	0	0	0	1	1	0
5	0	0	0	0	0	1	0	0	0	1	0	1
6	0	0	0	0	0	0	0	1	0	0	0	1
7	0	0	0	0	0	0	0	0	0	1	0	0
8	0	0	0	0	0	0	0	0	0	1	1	0
9	1	0	0	0	0	0	0	0	0	0	1	0
10	0	0	0	0	0	0	0	1	0	1	0	0
11	3	3	3	5	4	5	5	6	10	10	12	10
12	3	5	5	6	5	5	7	8	10	11	10	11
13	3	3	4	5	4	4	6	7	13	13	14	12
14	0	0	1	0	0	0	1	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	1	0
16	0	0	0	0	1	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	1	1	0	1	0
18	0	0	0	0	0	0	1	1	0	0	0	1
Total	10	11	14	16	14	17	21	27	34	41	42	37

The subjects of this study, encompassing children and adolescents, were selected to represent the study population for present investigation. The annual growth in height for each participant was calculated by dividing the yearly change in height by the age progression, with the average age increment being 0.892 ± 0.062 years. To preserve the original growth data, a cubic spline interpolation was applied to the annual velocity figures for everyone [11]. This method ensured that the growth patterns, particularly the age at peak velocity, remained unaltered [12].

In assessing size disparities at this pivotal developmental milestone, the peak linear growth height for each child was ascertained and subsequently employed in a covariance statistical analysis to discern patterns and correlations [13].

The annual incidence rate of distal radius fractures was determined by considering the entire population of Sindhudurg aged 0 to 18 years as the risk group. The denominator—age and sex-specific child-years—was extrapolated from the data provided by Census Bureau of India [14]. To account for variability, it was postulated that the number of child-years remained constant and that the incidence of distal radius fractures conformed to a Poisson distribution. This assumption facilitated the estimation of standard errors (Sєs) and the computation of 95% confidence intervals for the incidence rates.

To further elucidate the incidence rates across different demographics, crude incidence rates were stratified by age and sex for the period from 2000 to 2011. These rates were analyzed fusing generalized linear models with a Poisson error structure, which allowed for the fitting of the natural logarithms of the incidence rates as linear functions of age, sex, and the specified time period. This approach provided a nuanced understanding of the incidence trends and their potential determinants [15].

Approval was given by the institution review board and ethics committee of the institute. The informed consent was obtained from the patients and their families for inclusion in the study and subsequent publication.

Results

Within the twelve-year span of the study conducted in Sindhudurg, a total of 686 children and adolescents sustained distal radius fractures. The incidence rate of 4.24/1000 person-years (aged 0 to 18 years). There were 402 boys (58.6%) and 284 girls (41.4%). Detailed age-specific fracture rates for both genders are presented in Tables 1 and 2.

The study observed a notable increase in the number of fractures as documented in Table 3. The annual incidence of distal radius fractures per 100,000 individuals under 18 years in Sindhudurg escalated from 24 (95% CI 20.2 – 26.4) in 2000 to 54 (95% CI 46.3 – 69.6) in 2006, eventually stabilizing at 108 (95% CI 94.7 – 122.4) in 2011. The incidence rates in 2000 were found to be 28% higher compared to those in 2011 ($p < 0.001$). Specifically, the annual incidence rate for boys per 100,000 was 26% higher in 2011 than in 2000, which was 14 (95% CI 9.8 – 17.2). For girls, the annual incidence rate saw a 22% increase in 2011 compared to 10 (95% CI 7.7 – 14.4) in 2000. These increases were statistically significant for both genders (boys $p < 0.001$, girls $p = 0.01$), though the rate of increase did not significantly differ between them ($p = 2.8$). The disparity was primarily attributed to the differences in fracture rates, while the overall age-specific pattern remained consistent over the years.

An increase in undisplaced distal radius fractures resulting from simple falls was observed, alongside a decrease in the relative proportion of high-velocity injury-related displaced fractures. In boys, undisplaced fractures rose from 9 (95% CI 6.4 – 12.5) in 2000 to 39 (95% CI 33.7 – 45.8) in 2011, while in girls, the increase was from 6 (95% CI 3.8 – 9.1) in 2000 to 22 (95% CI 17.7 – 27.9) in 2011. Displaced fractures due to high-velocity trauma also increased in boys, from 5 (95% CI 2.9 – 8.2) in 2000 to 32 (95% CI 28.5 – 37.8) in 2011, and in girls, from 4 (95% CI 1.9 – 6.3) to 15 (95% CI 11.2 – 19.4) over the same period. These trends accounted for the overall changes in distal radius fracture rates between the two time periods, considering both simple falls and high-velocity trauma.

The school health examination program in Sindhudurg provided longitudinal data that revealed the mean age for peak velocity of growth to be 14.2 years for boys and 12.6 years for girls. The growth in linear velocity from the onset of the adolescent growth spurt to the peak of puberty was more pronounced in boys, averaging 3.2 centimeters per year, compared to 2.8 centimeters per year in girls.

Tables 1 and 2 plot the total number of distal radius fractures in healthy children under 18 years

Table 3: Secular change in Incidence of distal radius fracture in relation to mechanism of injury

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
BOYS												
Low velocity Injuries (undisplaced #)	9	10	9	11	11	13	18	17	20	34	40	39
	64.30%	58.80%	50.00%	61.10%	57.90%	54.20%	54.50%	50.00%	52.60%	62.90%	64.50%	54.90%
High velocity Injuries (displaced #)	5	7	9	7	8	11	15	17	18	20	22	32
	35.70%	41.20%	50.00%	38.90%	42.10%	45.80%	45.50%	50.00%	47.40%	37.10%	35.50%	45.10%
Total	14	17	18	18	19	24	33	34	38	54	62	71
	58.30%	60.70%	56.30%	52.90%	57.60%	58.50%	61.10%	55.70%	52.80%	56.80%	59.60%	65.70%
GIRLS												
Low velocity Injuries (undisplaced #)	6	7	8	10	9	9	13	17	19	25	26	22
	60.00%	63.60%	57.10%	62.50%	64.30%	52.90%	61.90%	62.90%	55.90%	60.90%	61.90%	59.50%
High velocity Injuries (displaced #)	4	4	6	6	5	8	8	10	15	16	16	15
	40.00%	36.40%	42.90%	37.50%	35.70%	47.10%	38.10%	37.10%	44.10%	39.10%	38.10%	40.50%
Total	10	11	14	16	14	17	21	27	34	41	42	37
	41.70%	39.30%	43.80%	47.10%	42.40%	41.50%	38.90%	44.30%	47.20%	43.20%	40.40%	34.30%
Total	24	28	32	34	33	41	54	61	72	95	104	108

throughout the study. These tables illustrate that the peak incidence of fractures correspond with the peak growth velocity in both boys and girls. The incidence of fractures peaked between the ages of 13.1 to 15.2 years in boys and 11.4 to 13.8 years in girls, indicating that the highest prevalence of distal radius fractures coincided with the period of maximum growth velocity. This longitudinal study design enabled a comparative analysis of both high and low velocity trauma-related distal radius fractures, affirming the relationship between growth spurts and fracture incidence.

Discussion

Our study demonstrates a significant increase in the incidence of distal radius fractures in children during the adolescent years, with a more pronounced difference in boys. These findings are in partial agreement with reports of other investigators in the developed world who reported similar gender differences in the incidence [16]. The literature on incidence of distal radius fractures in children is sparse in comparison with adults [17]. Many investigators have made similar observations of an overall increase in distal forearm fractures to the extent of 30% to 60% in girls and 31% to 35% in boys [18].

In the present study, we found little difference in the incidence rates in boys and girls younger than 10 years. The fracture rates rapidly increased thereafter to peak among boys between 13.1 to 15.2 years and 11.4 to 13.8 years in girls. Other investigators have found that the peak incidence of fractures occurs at the pubertal growth spurt which reaches maximum around 11 and 13 years in boys & girls respectively [19].

We were able to determine the age and pubertal stage at which statural height gain reached its maximum. Subsequent analysis confirmed the existence of a time lag between pubertal maturation and height gain. This period is considered as a phase, during which the long bones are relatively thin in comparison with soft tissue [20]. Analysis of data on morphometric variables in linear growth suggest that an asynchrony occurs at peak velocity of growth [21]. The greater height velocity in boys than girls (3.2 versus 2.8 centimeters per year) from the onset of adolescent growth spurt to the apex of puberty may help to explain excess distal radius fractures in boys [22].

The rapid decline in the incidence of distal radius fractures after the adolescents period in both sexes indicate the transient nature of this process [23]. There is a transient increase in cortical porosity of the distal radius, resulting from enhanced bone turnover at the time of maximal longitudinal bone growth [24]. This process may give rise to thinning of the metaphyseal cortex in distal radius, compromising bone strength [25]. The endocortical opposition cannot be increased further to reach a level where bone strength is able to provide adequate mechanical support [26, 27]. The increased incidence of distal radius fractures in children around the time of peak linear growth may represent an imbalance between the demands placed on the adolescent skeleton and the available bone mass [28, 29].

We found a larger number of undisplaced distal radius fractures due to simple falls in comparison with high velocity injuries. We found a similar tendency in adults sustaining distal radius fractures in our region [30].

Once longitudinal growth velocity slows down, cortical porosity gets corrected through improved bone deposition. Our findings corroborate this pattern, in that the incidence of distal radius fractures reduced following the age at which peak growth velocity was achieved (approximately 12.6 years in girls and 14.2 years in boys).

Adolescent skeletons face increased demands due to growth, but bone mass might not fully support their day-to-day needs [31]. This study demonstrates that undisplaced distal radius fractures occur more frequently due to simple falls. High-velocity injuries were less common.

The strength of this study is its longitudinal nature, spread over a span of 12 years. This allowed us to clearly identify the key maturational events of morphometric and physiological variables including peak velocity of growth. We were able to draw definitive conclusions since this study cohort is large and included all the children in our district.

A possible drawback of the study was that the anthropometric measurements did not exactly coincide with the occurrence of fractures. This was because our school health screening programme was arranged for the entire academic year in advance by the District School Health Examination Committee covering all anganwadi, primary and secondary, and pre-university course schools.

In summary, this study provides valuable insights into fracture patterns during growth and adolescence. Understanding the interplay between growth, bone strength and fracture risk during adolescence is crucial for preventive measures. Further research can help elucidate the underlying mechanisms, guide interventions to reduce fractures in this vulnerable population, optimize preventive strategies and promote bone health in children and adolescents.

Conclusion

This 12-year longitudinal study reveals a statistically significant increase in the incidence of low-energy distal radius fractures during the adolescent years, among otherwise healthy children and adolescents in Sindhudurg. The age at peak incidence of distal radius fractures closely aligns with the age at which peak growth velocity in height occurs in both boys and girls. During the pubertal growth spurt, distal radius bone strength lags behind the escalating mechanical demands, likely due to declining cortical thickness. This phenomenon gives rise to the novel "Transient Distal Radius Fragility Fracture Hypothesis" in children.

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Declaration of patient consent : The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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