Original Article

OPEN ACCESS

The role of greulich and pyle method in age estimation from left hand plain x-rays

Sohail Kamran[1] , Ayesha Haider[2] , Asadullah[3]

[1]Radiologist Department of Diagnostic Radiology, National Institute of Rehabilitation Medicine Islamabad
[2]Assistant Professor Department of Forensic Medicine Federal Medical & Dental College Islamabad
[3]Department of Forensic Medicine Bannu Medical College Bannu

Author`s Contribution

[1]Drafting the work or revising it critically for important intellectual content
[2]Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work.
[3]Final approval of the version to be published

Funding Source: Nil
Conflict of Interest: Nil

Received for Publication: February 23,2019
Accepted for Publication: June 30, 2019

Address of Correspondent
Dr. Ayesha Haider
Assistant Professor Department of Forensic Medicine Federal Medical & Dental College Islamabad
drayeshahaider@hotmail.com

***Cite this article as**: Kamran S, Haider A, Asadullah. The role of greulich and pyle method in age estimation from left hand plain x-rays. Ann Pak Inst Med Sci. 2019; 15(1): 12-16.*

ABSTRACT

Objective: To determine whether the Greulich and Pyle (G&P) atlas is applicable to populations of different ethnicity.

Material and Methods: ~~A~~ cross sectional study was conducted at Department of Diagnostic Radiology, National Institute Rehabilitation Medicine during 2017. Total 100 left hand and wrist radiographs were assessed using GP atlas for age estimation using non-probability consecutive sampling technique.

Mean Chronological age (CA) and Skeletal age (SA) were calculated for each group and any significant differences between the two were established through two- tailed, paired t-test. Data was analyzed using SPSS version 17.

Results: Total of 100 patients with left hand and wrist x-rays were included (50 males, 50 females). Analysis showed a strong correlation between Chronological age (CA) and Estimated age (skeletal age) with a p <0.001. The mean difference between chronological age and skeletal age was .31050 years and std. Deviation 1.06866 respectively; p-values < 0.001. However, a strong significant positive correlation (r = .980; p-values, 0.001) was noted between chronological age and skeletal age in both the genders.

Conclusion: GP atlas can be used for age estimation to Islamabad Rawalpindi population but would recommend that differences highlighted are to be taken in to consideration for over- and under-aging.

Key words: Greulich-Pyle Atlas, Chronological age, Skeletal Age.

Introduction

Determination of the age of an individual from the appearance and fusion of the ossification centers is considered a reasonable scientific method and a well-accepted fact in the field of medical and legal professions.[1] It is a well-established fact that skeletal development is indicated by increase in size and maturity. Growth is a continuous biologic process and is genetically determined however pattern of skeletal maturity can be altered by environmental factors. There is a definite sequence of date of appearance for centers of ossification but schedule is altered by metabolic or constitutional disturbances. Skeletal development varies between populations and depends on race and sex. The developmental status of a child is usually assessed in relation to events that take place during the progress of growth. Thus, chronological age, dental development, height and weight measurements, sexual maturation characteristics and skeletal age are some biological indicators that have been used to identify stages of growth.[2] The bone age of a child indicates his/her level of biological and structural maturity better than the chronological age calculated from the date of birth.[3]

Since Heinrich von Ranke introduced the use of the hand X-ray to evaluate pediatric growth in 1896, this method has become an important tool in the assessment of the normal and pathologic development of children.[4] Skeletal maturity assessment is clinically essential for pediatric orthopedics in preoperative planning[5, 6] for the diagnosis and treatment of pediatric growth development failure due to congenital or iatrogenic endocrinological disorders or after chemotherapy or radiation therapy of oncologic patients.[7–10]

Greulich & Pyle (GP) atlas is one of the most popular method to assess sub adult skeletal age [11, 12], which shows a good correlation with the chronological age.[13, 14, 15] The principle of simple method consists of comparing a given hand radiograph with a series of reference radiographs from boys and girls of certain age groups and selecting the nearest match.[16]

Based on radiological examination of skeletal development of the wrist, bone-age is assessed and then compared with the chronological age. A discrepancy between the two values indicates abnormalities in skeletal development. Data regarding skeletal maturity is well documented in the west however there is paucity of such data for Pakistani population. The present study will focus on local population of Islamabad Rawalpindi and will include individuals of both sexes between 0 to 19 years of age by evaluating the radiological age based on X-rays of the wrist and hand.

Methodology

A comparative cross-sectional study was conducted at Diagnostic Radiology Department of National Institute of Rehabilitation Medicine Islamabad during year 2017.The study participants were both boys and girls of Islamabad & Rawalpindi origin; having chronological age less than 19 years determined by their birth certificate, visiting to the radiology department of NIRM .

Those with gigantism (means Acrodactyly), Turner's syndrome (short 4 metacarpal), Klinefelter's syndrome (angulation at an interphalangeal joint affecting 5 digit), Marfan's syndrome (spider fingers), Hurler's disease (pointing of proximal metacarpals), Achondroplasia (short hands with stubby fingers, separation between the middle and ring fingers) were excluded from the study. Patients other than Islamabad Rawalpindi origin and refugees were excluded to remove bias from the results.

A total of 100 participants; 50 Boys and 50 Girls of 0 to 19 years age visiting out patients department and Diagnostic Radiology Department National Institute of Rehabilitation Medicine Islamabad fulfilling the inclusion criteria were included. Approval of the study was taken from the hospital ethical committee. Informed written consent was taken from the guardian of the children before including in the study.

The estimated bone age from hand and wrist x-ray results were interpreted by use of Greulich Pyle atlas and correlated by the radiologist for estimation of skeletal age. The Mean difference between SA and CA was documented and differences in years were assessed in all ages using Greulich Pyle atlas as a reference.

The Radiology Information System of NIRM hospital was used to retrieve all Hand-Wrist radiographs of patients with chronological age (CA) less than or equal to 19 years at the time of exposure. CA was determined from hospital records to the nearest month. After an interval of four weeks, one hundred randomly selected radiographs were reviewed independently by both reviewers, blinded to the CA at this point too. Pearson's Correlation coefficient (r) was calculated to assess inter-observer reliability and paired t-test was used to identify any significant difference between SA (Fig 1) estimations by the two observers.

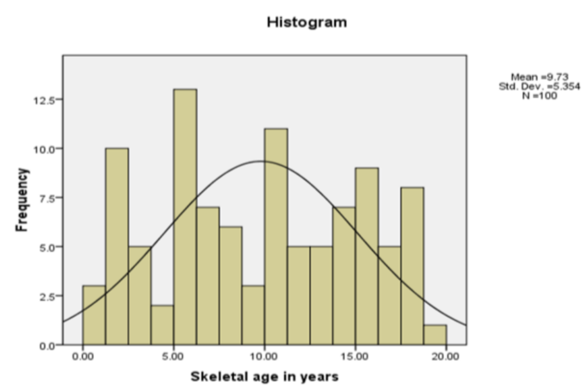

Figure 1. Histogram of skeletal age of the patients (n=100)

In general, the highest agreement between bone age and chronological age was for the ossification centers of distal epiphysis of ulna, radius and metacarpal bones. Observer was blind to information on CA at the time of assessment of the radiographs to avoid bias of the results. The relationship between CA and SA was examined for each one year age group to determine the applicability of the method to Islamabad Rawalpindi population. Basic demographic information including name, gender, CA

and estimated age by Greulich Pyle Atlas was recorded on a predesigned Proforma.
Data analysis was performed using the (SPSS V17) statistical software. Descriptive statistics were used to calculate mean and standard deviation for Quantitative variables like chronological age, skeletal age, difference in chronological age and skeletal age. The difference between CA and SA was calculated by subtracting the CA from the SA. A negative value indicated that the individual had been under age and a positive value indicated an individual being over age using the GP atlas. Frequency with percentages was presented for Qualitative variables like gender and age. Spearman correlations coefficient was applied to correlate chronologic age to skeletal age in both genders. P-value≤ 0.05 was considered significant.

Results

This prospective study i total of 100 individuals aged between 0 to 19 years.

The mean difference between chronological age and skeletal age was .31050 years and std. Deviation 1.06866 respectively; p-values < 0.001). However, a strong significant positive correlation (r= .980 respectively; p-values, 0.001) was noted between chronological age and bone age in both the genders (Table I-III)
The scatter plot indicated in (Fig 2) represent a positive linear association between skeletal and chronological age for females subjects. Pearson's correlation coefficient was also conducted between skeletal and chronological age. A strong correlation coefficient of 0.98 was found between skeletal and chronological age for both female and male subjects ($p < 0.05$). The results of the Pearson's correlations were being conducted. Strong correlations were found in all cases, with statistical significance also being found in all four cases ($p < 0.05$). Additionally, the 95% confidence intervals calculated for each of these four correlations also indicated positive correlations being present across these confidence intervals.

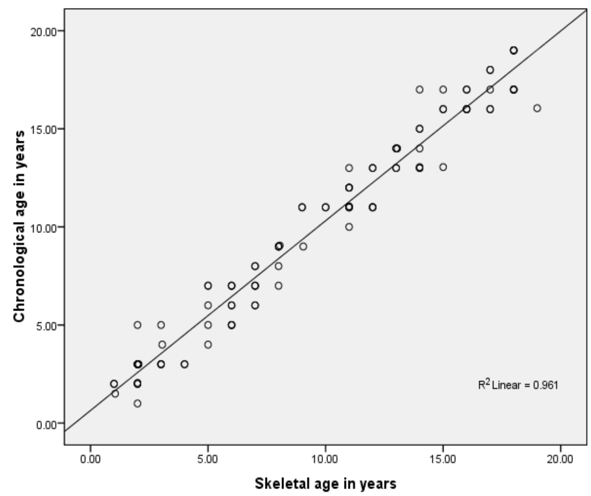

Figure 2. Scatter plot between chronological age and skeletal age in years (n=100)

Discussion

Study indicates that there is a great variation in the chronological age and bone age calculated by the Greulich & Pyle Atlas. Various international studies have reported different results regarding the applicability of the Greulich & Pyle Atlas for estimation of chronological age. In Australia, bone ages of males are on average advanced by 0.4 years, whereas bone ages of females on

Table I: Correlation and independent t-test between chronicle age and skeletal age

	N	Mean	Std. Deviation	Std. Error Mean	X^2	p-value	t-test
Chronological age in years	100	10.0505	5.29088	.52909	0.98	0.00	2.90
Skeletal age in years	100	9.7400	5.34018	.53402	0.98	0.00	

Table II: Paired Samples Test between Chronological age and skeletal age.

	Paired Difference					T	Df	Sig.(2-tailed)
	Mean	Std.Div	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Chronological age in years-Skeletal age in years	0.31	1.06	0.10	0.09	0.52	2.90	99	0.05

Table III: Correlation and regression coefficient for both male and female for the age estimation with chronological and skeletal age.

		Chronological age in years	Skeletal age in years
Chronological age in years	Pearson Correlation	1	.980**
	Sig. (2-tailed)		.000
	N	100	100
Skeletal age in years	Pearson Correlation	.980**	1
	Sig. (2-tailed)	.000	
	N	100	100

average are skeletally delayed by 0.3 years when using this atlas.[17] Another study found significant difference in chronological and bone ages in Israeli boys.[18] However, statistically significant difference between the means and standard deviations of up to one year has been reported between chronological age and bone age of Turkish children.[19]. However, our results are consistent with Shaikh et al[20] who performed a similar study on children aged 8-18 years at Chandka Medical College, Larkana, and reported mean differences of ages in females and males as 0.5 and one year respectively. Zafar et al[21] who compared bone and chronological ages at the Agha Khan University Hospital Karachi also found that the mean differences between the ages was less in females as compared to males in children of middle and late childhood.

However, there is a high correlation between the two ages in both genders, which makes serial measurements of bone age useful in diagnosing and treating endocrine disorders of growth and stature.

In the last few decade scholars debate on the effect of puberty, nutrition, socioeconomic status, geographic location and ethnicity on skeletal maturation and skeletal age in both sexes. Age has been indicated as one of the most essential factors for establishment of the identity of an individual and determination of the growth factors related to the individual. The question raised over past decades in multiple studies conducted worldwide is to whether the Greulich and Pyle standards set in 1959 are still applicable on current population and also whether the population skeletal maturation used at that time is different to current population. To answer these questions a multicenter longitudinal study needs to be undertaken [22, 23] including children of all races and ethnicity and taking into account different geographic locations. As this is a set standard and is used in important fields of life like medical field for assessing growth abnormalities and response to treatments, forensic, criminal and legal cases for trafficking victims and illegal immigrants. The gap between chronological and skeletal age though small for most of the data but the outliers in the current study should be considered when assigning age in forensic use due to the fact that in clinical situations the date of birth is provided but in forensic situations the history and background for age estimation is not known in most of the cases. The gap can still be justified with the fact that maturation changes with respect to time. According to Himes,[24] there is 0.22-0.66 years increase in skeletal maturation per year with changes seen more in ages of fusion.

All the outliers were included in the study as it is true representation of the data. The reason for the few outliers may be due to the systematic error on the assessor's part for example a bone can be over-aged or under-aged than its actual value causing variations in the results. However, it should be noted that it is random and could increase the variation when being considered on its own but balancing the error when taken in group. The variability in assessing the skeletal age is lower for the carpal bones as compared to other bones of the hand-wrist.[25, 26] The other possible reason could be that at the time of presenting to Emergency Department with trauma there might have been an underlying pathology which was not diagnosed or was not apparent at that time.

Conclusion

There is strong correlation between skeletal age and chronological age among the study participants after applying the Greulich and Pyle (1959) atlas method. Current study has not found any evidence against the applicability of Greulich and Pyle (1959) atlas on the basis of changes in specific bony maturation patterns despite of variability in maturation rates. Application of the Greulich and Pyle (1959) atlas method should be encouraged among the assessors and researchers who want to determine the relationship between the chronological age and the skeletal age in the field of medicine. The current study supports the use of Greulich and Pyle (1959) method in the age estimation among

Pakistani population as long as differences highlighted in our study are taken in to consideration.

References

1. Baumann U, Schul R, Reisinger W, Heinecke, A,Schmeling A, Schmidt, S. Study on the time frame for ossification of distal radius and ulnar epiphysis on hand radiographs. Forensic Sci Int. 2009;191(1-3):15-18.
2. Mahajan S Evaluation of skeletal maturation by comparing the hand wrist radiograph and cervical vertebrae as seen in lateral cephalogram. Ind J of dental Res. 2011; 22(2): 309-16.
3. Mughal AM, Hassan N, Ahmed A. Bone age assessment methods: A critical review. Pak J Med Sci. 2014; 30(1): 211-215.
4. Horter MJ, Friesen S, Wacker S, Vogt B, Leidiger B, Roedl R, et al. Determination of skeletal age: comparison of the methods of Greulich and Pyle and Tanner and Whitehouse. Der Orthopade 2012;41(12):966–976.
5. Sabharwal S, Sakamoto SM, Zhao C. Advanced bone age in children with Blount disease: a case-control study. J Pediatr Orthop.2013;33(5):551–557.
6. Heuschkel R, Salvestrini C, Beattie RM, Hildebrand H, Walters T, Griffiths A. Guidelines for the management of growth failure in childhood inflammatory bowel disease. Inflamm Bowel Dis.2008;14(6):839–849.
7. Even L, Andersson B, Kristrom B, Albertsson-Wikland K, Hochberg Z. Role of growth hormone in enchondroplasia and chondral osteogenesis: evaluation by X-ray of the hand. Pediatr Res. 2014;76(1):109–114.
8. Darendeliler F, Ranke MB, Bakker B, Lindberg A, Cowell CT, Albertsson-Wikland K, et al. Bone age progression during the first year of growth hormone therapy in pre-pubertal children with idiopathic growth hormone deficiency, Turner syndrome or idiopathic short stature, and in short children born small for gestational age: analysis of data from KIGS (Pfizer international growth database).Horm Res. 2005;63(1):40–47.
9. Bree AF, Siegfried EC. Acne vulgaris in preadolescent children: recommendations for evaluation. Pediatr Dermatol. 2014;31(1):27–32.
10. Lazar L, Phillip M. Pubertal disorders and bone maturation. Endocrinol Metab Clin N Am. 2012;41(4):805–825.
11. Black S, Aggrawal A, Payne-James J. Age Estimation in the Living: The Practitioner's Guide. Chichester (UK): John Wiley & Sons;2010.
12. Gilsanz V, Ratib O. Hand Bone Age. A Digital Atlas of Skeletal Maturity. 2ed. Berlin (Germany): Springer;2012.
13. Cameriere R, Ferrante L, Mirtella D, Cingolani M. Carpals and epiphyses of radius and ulna as age indicators. Int J Legal Med. 2006;120(3):143–146.
14. Schmidt S, Koch B, Schulz R, Reisinger W, Schmeling A. Studies in the use of the Greulich - Pyle skeletal age method to assess criminal liability. Leg Med. 2008 ;10(4):190-195. doi:10.1016/j.legalmed.2008.01.003.
15. Tisè M, Mazzarini L, Fabrizzi G, Ferrante L, Giorgetti R, Tagliabracci A. Applicability of Greulich and Pyle method for age assessment in forensic practice on an Italian sample. Int J Legal Med. 2011;125:411-416. doi:10.1007/s00414-010-0541-6.
16. Bull RK, Edwards PD, Kemp PM, Fry S, Hughes IA. Bone age assessment: a large scale comparison of the Greulich and Pyle, and Tanner and Whitehouse (TW2) methods. Arch Dis Child. 1999;81(2):172–173. doi:10.1136/adc.81.2.172.
17. Lin N-H, Ranjitkar S, Macdonald R, Hughes T, Taylor JA, Townsend GC. New growth references for assessment of stature and skeletal maturation in Australians. Aust Orthod J. 2006;22(1):1–10.
18. Soudack M, Ben-Shlush A, Jacobson J, Raviv-Zilka L, Eshed I, Hamiel O. Bone age in the 21st century: is Greulich and Pyle's atlas accurate for Israeli children? Pediatr Radiol. 2012;42(3):343-348. doi:10.1007/s00247-011-2302-1
19. Buken B, Safak AA, Yazici B, Büken E, Mayda AS. Is the assessment of bone age by the Greulich-Pyle method reliable at forensic age estimation for Turkish children? Forensic Sci Int. 2007;173(2-3):146–153. doi:10.1016/j.forsciint.2007.02.023
20. Shaikh AH, Rikhasor RM, Qureshi AM. Determination of skeletal age in children aged 8-18 years. J Pak Med Assoc. 1998;48(4):104–106.
21. Zafar AM, Nadeem N, Husen Y, Ahmad MN. An appraisal of Greulich-Pyle Atlas for skeletal age assessment in Pakistan. J Pak Med Assoc. 2010;60(7):552–555.
22. Loder RT, Estle DT, Morrison K, Eggleston D, FishDN, Greenfield ML, Guire KE. Applicability of the Greulich and Pyle skeletal age standards to Black and White children of today. Am J Dis Child. 1993; 147: 1329-1333.
23. Ontell FK, Ivanovic M, Ablin DS, Barlow TW. Bone age in children of diverse ethnicity. Am J Roent- genol. 1996; 167(6): 1395-1398.
24. Himes JH. An early hand-wrist atlas and its implications for secular change in bone age. Ann Hum Biol. 1984; 11(1): 71-75.
25. Thompson GW, Popovich F, Luks E. Sexual dimorphism in hand and wrist ossification. Growth. 1973; 37: 1-11.
26. Roche AF, Davila GH. The reliability of assessments of individual hand-wrist bones. Hum Biol. 1976; 48: 585-597.