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Assessment of Reliability of Greulich and Pyle (GP) Method for Determination of Age of Children at Debre Markos Referral Hospital, East Gojjam Zone

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ABSTRACT

BACKGROUND: Greulich and Pyle standards are the most widely used age estimation standards all over the world. The applicability of the Greulich and Pyle standards to populations which differ from their reference population is often questioned. This study aimed to assess the reliability of Greulich and Pyle (GP) method for determination of age of children at Debre Markos Referral Hospital, East Gojjam Zone, Ethiopia.
SUBJECTS AND METHODS: Hospital based cross sectional study design was applied to children who came to Debre Markos Referral Hospital from May to October 2015 and fulfilled the inclusion criteria of the study. The data was analyzed using SPSS version 20 and medcalc version 15 softwares. Significance was set at α = 0.05.
RESULTS: A total of 108 radiographs were analyzed. Chronological age in most of the children was under estimated. The mean under-estimation was 11.8 months in the female sample and 8.7 months in the male sample. Greulich and Pyle method became inapplicable for the sample at 16 years for females and 16.5 years for males and later. Delay in skeletal maturation was observed in both sexes, but the females in the sample matured earlier than the males.
CONCLUSION: The findings of this study suggest against the applicability of GP atlas which were not directly applicable to an East Gojjam Zone population. Large scale studies should be planned and nationwide guideline, and atlas which can easily be used throughout the country should be developed.
KEYWORDS: Chronological age, bone age, Greulich and Pyle

INTRODUCTION

There are different measures of age: biological, social, psychological age and chronological age. Chronological age has gained salience in response to the development of laws and policies that rely on age as a marker or boundary (1). A range of medical, physical and psycho-

social assessments as well as approaches to determine age that make use of existing local knowledge are most common methods of carrying out assessments of chronological age (2) .However, most experts agree that age assessment is not a determination ofchronological age but an educated guess, and can only ever provide an indication of skeletal or developmental maturity from which conclusions about chronological age may be inferred (2) .

Skeletal age, or bone age, the most common measure for biological maturation of the growing human, derives from the examination of successive stages of skeletal development, as viewed in hand-wrist radiographs (3) . Estimation of skeletal age is a means of assessing development and the process of skeletal maturation in children and adolescents for clinical or forensic purposes (4). These assessments involve comparing the skeletal age of a test population against established standards (5). For this purpose, various techniques are available, which are based on the understanding of the patterns of skeletal development (6) .

Greulich and Pyle standards are the most widely used age estimation standards all over the world. These standards were derived from a longitudinal study carried out in 1931 on children of North European ancestry with high socioeconomic status who were born in the United States of America with sample population comprising 1000 children (7) .

The applicability of the Greulich–Pyle standards to populations which differ from their reference population is often questioned. This skepticism is the result of its nature-a standard is based on the results of a specific study performed on a specific population at a specified point in time (8). Current age estimation using bone development in the hand and wrist is based on the standards developed by Greulich and Pyle in 1959. However, these skeletal age estimation standards are based on a study of wrist radiographs of Euro-American children.

In the living(life) age determination is the most important issue to the court and to the common citizens as well (9) . An over or under-estimation of bone age can result in the inappropriate diagnosis and treatment of growth disorders, unjust punishment, misplacement in a new school or undue advantage in competitive sports (10).

In Ethiopia, research on the reliability of Greulich and Pyle method was not done while the method is utilized for determination of age. The main objective of the study is to assess the reliability of Greulich and Pyle (GP) method for determination of age of children at DebreMarkos Referral Hospital.

SUBJECTS AND METHODS

Study design: Hospital based cross sectional study design was applied. Conventional plain radiographs of the hands and wrists were obtained from people who meet the study criteria.

Study area and time: DebreMarkos, the capital of East Gojjam Administrative Zone, is located in the Northwest of the capital city of Ethiopia, Addis Ababa, at a distance of 300Kms. It is also found at a distance of 265 kms to the capital of Amhara Nation Regional State, Bahir Dar. DebreMarkos Referral Hospital is found in Debre Markod Town. The study was conducted from May 2015 to October 30, 2015.

Source population: All patients coming to radiology department for x-ray service were taken as source population.

Study population: All patients who came to the hospital at Radiology Unit for wrist and hand x-ray were selected for the sample.

Inclusion criteria: All patients of 10 to 22 years of age who had wrist radiography at inpatient ward were taken as part of the sample. All patients at outpatient department who were ordered for wrist and hand x-ray for ruling out of differential diagnosis were included in the study.

Exclusion criteria: Patients with congenital anomaly over the hand and wrist; who didn't know their chronological age were not included. Further more medico-legal issues, radiographs with poor clarity, and any severe fracture over the hand and wrist that hinder determination of age were excluded.

Sample size and sampling method: Purposive sampling technique was applied. All children who came to the hospital from May to October, 2015 and fulfilled the inclusion criteria of the study were taken as total sample size.

Variables of the Study: Sex and chronological age were the independent variables of the study. On the other hand, skeletal age determined by Greulich and Pyle method were the dependent variables.

Data collection procedure: Chronological ages of the children were obtained from their parents or taken from the patient cards. The radiograph films were collected from the technicians and were viewed using a standard light box in manual x-ray machine. From the digital x-ray machine, the images were automatically saved and seen from the screen at the department of Radiology at Debre Markos Referral Hospital(DMRH). The skeletal ages were determined using Greulich and Pyle atlas.

Data quality assurance: In order to ensure the quality of the data, the investigator was trained by the radiologist. Furthermore, the investigator worked under the supervision of the radiologist. The films that were clear were selected.

Data analysis: Data analysis was performed using SPSS statistical software (version 20) and medcalc version 15. The results of all the analyses were summarized and then compared to the results from other populations on which the GP method was applied. Significance was set at $\alpha = 0.05$.

Ethical consideration: Ethical clearance was obtained from Institutional Review Board (IRB) of the college of Health Sciences, Addis Ababa University.

RESULTS

General distribution of the sample: A total of 108 children, male 65(60.2%) and female 43 (39.8%), aged 10 to 22 years were included in this study. Although assessment of ethnicity as a factor in determination of age was planned, different ethnic groups could not be found in the area since all were Amharas. Samples were grouped according to GP atlas. The left hand and wrist were studied. Age estimation analysis was performed on the left hand unless it was too damaged, or the radiographs were unclear or incomplete.

Age and sex distribution of the sample: The age groups used follow those used in the Greulich and Pyle Radiographic Atlas of Skeletal Development of the Hand and Wrist which had whole and half year category. However, in the current sample, there was no half year category since there were no subjects who fell in the category.

Skeletal age analysis, difference between skeletal age and chronological age for the whole hand: Once the radiographs had been aged using the GP method, the estimated Skeletal Age (SA) was compared to the known chronological age (CA). This was done for the samples grouped according to the SA as determined by the GP method which records a maximum age of 18 years for females and 19 years for males using the bones of the hand and wrist. Skeletal ages for the known CA's of each of the SA single year categories were averaged, and the results are presented in Table 1 for males and Table 2 for females.

The mean SA values are generally less than the corresponding CA. Thus, the GP method is underestimating age for all age groups except 14, 15, 16 years in the male sample and 14 years in the female sample. The mean underestimation was 11.8 months in the female sample and 8.7 months in the male sample (Tables 2 and 3).

A comparison of the variability of the two samples confirms that the females show more consistency (13.7%) in the underestimation of SA than the male sample (18.0%) (Tables 1 and 2). Significant correlations were found to exist between Skeletal Age (SA) estimated using the GP method and the Chronological Age (r_s=0.912,$p = $ .000 for males and r_s=0.761, $p = $ .000 for females). These values are significant at α level 0.05, and show strong positive correlation between CA and SA which means that both are measuring an increase in age. The presence or absence of significant difference between the CA and SA as determined by the GP age estimation method was assessed by Mann-Whitney test. For the male sample ($U = $ 1616.00, $p = $ 0.0196) and the female sample ($U = $593.50, $p = $ 0.0029) were recorded indicating that there was a significant difference between CA and SA.

A multiple comparison was performed for each age group using the Kruskal-Wallis test. It showed that a significant age differences occurred at 14,19, 20 , 21 and 22 years of age in females (P = 0.000325), and 21 and 22 years of age in males (P < 0.000001).

Table 1: Chronological Age Grouped by Skeletal Age for males

Chronological age (CA)		Skeletal age (SA)			Difference	CA-SA
	N	Mean	SD	CV	Years	Month
Males						
10	4	9.875	1.9311	20.8%	0.125	1.5
11	2	10.000	0.0000	0.0%	1.0	12
12	1	11.000	*	*	1.0	12
13	2	12.250	0.3536	2.9%	0.75	9
14	3	14.333	1.0408	8.0%	-0.333	-4
15	3	15.667	2.0817	14.9%	-0.667	-8
16	7	16.571	0.7868	5.4%	-0.571	-6.9
17	4	16.750	1.7078	10.5%	0.25	3
18	8	16.938	1.4745	8.7%	1.062	12.7
19	2	18.500	0.7071	3.8%	0.5	6
20	11	18.727	0.6467	3.7%	1.273	15.3
21	4	19.000	0.0000	0.0%	2.0	24
22	14	19.000	0.0000	0.0%	3.0	36
Total	65	16.746	2.9845	18.0%	0.7	8.7

Table 2: Chronological Age Grouped by Skeletal Age for Females

Females Chronological age (CA)		Skeletal age (SA)			Difference	CA-SA
	N	Mean	SD	CV	Years	Month
10	1	8.00	*	*	2.0	24
11	1	10.00	*	*	1.0	12
12	1	10.00	*	*	2.0	24.0
13	1	13.00	*	*	0.0	0.0
14	1	18.00	*	*	-4.0	-48
15	1	13.50	*	*	1.5	18
16	3	16.00	1.00	6.2%	0.0	0.0
17	5	16.20	1.0954	7.0%	0.8	9.6
18	7	17.71	0.756	4.5%	0.3	3.6
19	6	18.00	0.00	0.0%	1.0	12.0
20	5	18.00	0.00	0.0%	2.0	24.0
21	1	18.00	*	*	3.0	36.0
22	10	18.00	0.00	0.0%	4.0	48.0
Total	43	16.94	2.215	13.7%	0.98	11.8

Table 3: Percentage of Skeletally Mature Individuals per Chronological Age Group

Males	CA	N	Individuals With Complete Epiphyseal Fusion	
			n	%
	17	4	1	25
	18	8	2	25
	19	2	1	50
	20	11	9	82
	21	4	4	100
	22	14	14	100
Females				
	17	5	1	20
	18	7	6	85.7
	19	6	6	100
	20	5	5	100
	21	1	1	100
	22	10	10	100

Figures 1 for females plot shows the magnitude of the difference in years between CA and SA for individuals in the sample. The scatter plots show an over- or under- estimation of age according to the GP skeletal age estimation. That is, for 83% of the male and 68% of the female sample, CA was underestimated. GP skeletal age estimation method became less accurate in older individuals in both female and male samples.

Bland Altman Plot of males (Figure2) shows a mean difference of 1.12 years between chronological age and bone age. Specifically, 95% of the points lie between -1.9 years and +4.1 years. For females, the mean difference was 1.6 years, and 95% of the points lie between -1.9 years and +5.0 years. Figure 2 also shows the point at which GP became inapplicable for the sample. It is 16.5 years for males which is characterized by the increased number of estimates falling outside of the two standard deviation limits. GP for females became inapplicable at 16 years.

Termination of growth and atainment of maturity: Table 3 shows individuals who had reached full skeletal maturity before 19 years of age for males and 18 years of age for females. It also shows those children who did not reach full maturity.

As shown in Table 3, individuals who were 19 years chronologically in male sample reached skeletal maturity in 50% of the group. The remaining individuals had not yet attained maturity and were below 19 years of age which indicates delay in skeletal maturation. At 20 years of age, 82% of individuals reach maturity and 100% at 21 years of age. The females in the sample matured earlier than the males. At 18 years of age, 85.7% individuals reached full maturity at 19, being 100%.
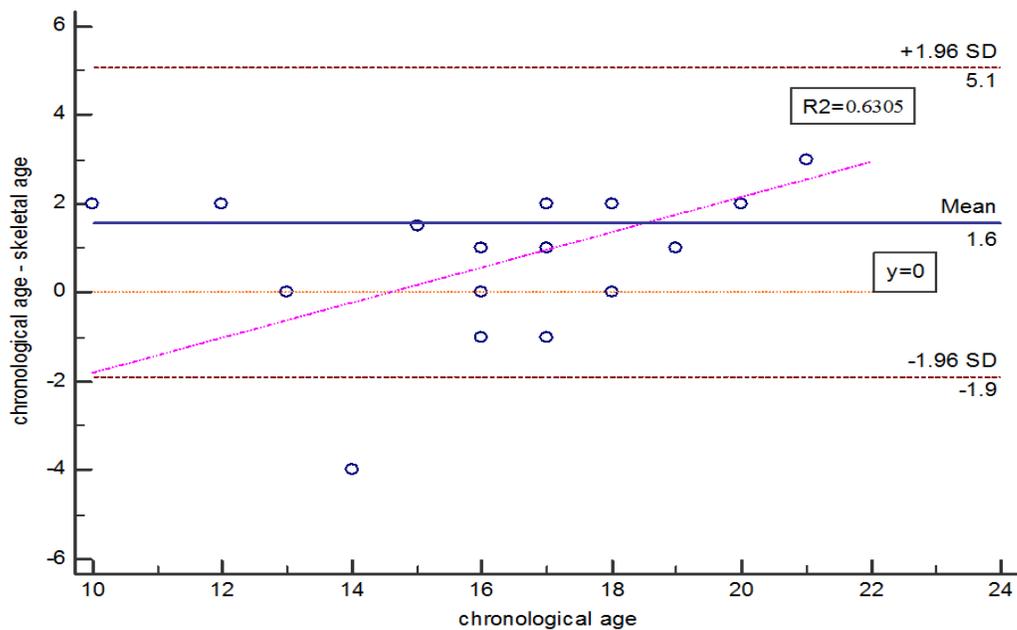
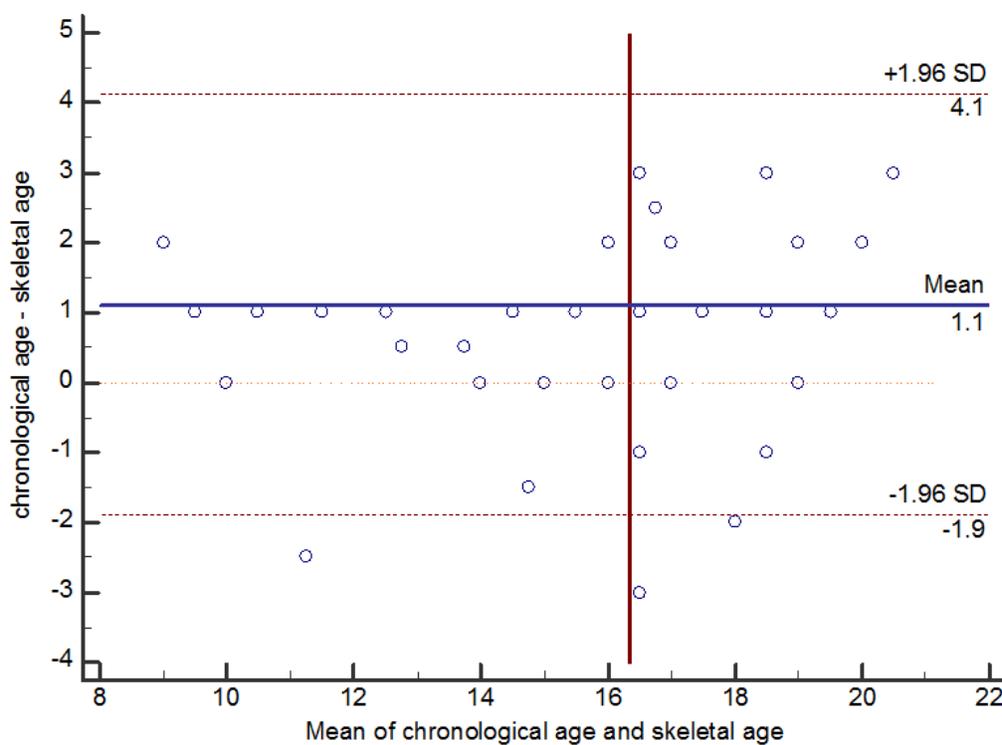*Figure 1*: *Scatter plot illustrating the difference between CA and SA for the female data against CA*

Figure 2: *Bland-Altman (1986) Plot showing the difference between SA and CA for the male sample plotted against the average age given by the two methods*

DISCUSSION

The applicability of the GP standards to modern day populations has been tested over the past few decades. Various international studies have reported different results regarding the applicability of the Greulich and Pyle atlas for estimation of chronological age. Differences in growth rate and maturation which were noted when the Greulich and Pyle standards were applied to contemporary populations have been attributed to secular trends and differences in genetic origin, health status and economic status (8,11). These factors influence growth and skeletal development, causing varying effects on different populations which affect the direct applicability of the Greulich and Pyle standards to various populations (5). The present study examined the applicability of the Greulich and Pyle method of age determination in the context of Ethiopia, East Gojjam Zone.

The total sample size was 108; male (65) and female (43) of 10 to 22 years of age. This was done in order to ascertain the earliest age at which full skeletal maturity characterized by complete epiphyseal closure could be observed and the latest age at which incomplete epiphyseal fusion was observed. According to a study in South Africa, the oldest age at which non-fusion was observed was 21 years in the male sample and earliest age at which complete fusion was observed was 14.6 years in the female sample (6). In India, epiphyseal fusion was not completed at 20 years of age in both sexes, and the earliest age by which completed epiphyseal fusion seen was 17 years of age(12). In the current sample, the earliest age at which complete fusion was observed was 14 years in the female sample, and the oldest age at which non-fusion was observed was 20 years in the male sample.

Significant correlations were found to exist between skeletal ages estimated using the GP method and chronological ages (5,6,10,13-15). Similar to the above findings, significant correlations existed in the current sample and confirmed a positive linear correlation which indicates that CA varies as SA varies.

Researchers in different countries showed that skeletal ages determined using the Greulich and Pyle method were lower than the chronological ages for a large proportion of the sample both in males and females, and that the method underestimates chronological age (5,6, 16, 17). Although the difference is not significant, a study in Australia reported overall underestimation of skeletal age by 2.2 months: 1.5 months for females and 3.7 months for males (18).

In India, researchers concluded that the method was not applicable to the Indian children of both sexes and recorded a difference of 0.7 years for males and 0.33 years for females (12). Similarly, another study in India recorded a difference of 0.02 years for girls and 0.23 years for boys (15). In Pakistan, there was a mean differences of up to 13 months (19). While a discrepancy of up to 20 months (16) was reported in a Malawian sample, in Iran, authors showed a difference of 2 to 21.6 months in boys and 6.6 to 11.9 months in girls aged from 7-14 years and concluded the possibility of different pattern of skeletal maturation among Kurdish children than the reference (20).

In South Africa, researchers showed that the average difference between the chronological and skeletal ages was 0.5. Similarly, another researcher in this country reported a mean difference of 12 months for females and about 6.8 months for the males (5,6,21).

In this study, overall results showed that skeletal ages determined using the Greulich and Pyle method were lower than the chronological ages for a large proportion of the sample both in males and females and that the method underestimates chronological age (i.e., SA is less than CA). The mean difference was 11.8 months for females and 8.7 months for males. SA was generally less than CA. The difference was significant for both male and female samples, and this significant difference occurred at 14, 19, 20, 21 and 22 years of age in females, and 21 and 22 years of age in males.

Contrary to the above findings, a study in Scotland, Pakistan, Australia and Dutch found no significant difference between chronological age

and estimated age using the Greulich and Pyle atlas for both males and females(18,22-24). This may be due differences in biological origin, health status and economic status (2,8,11).

Bland-Altman (1986) plots for the male and female samples measure the agreement between the two methods by plotting the average of the two measurements (SA and CA) against the difference between them (CA-SA). These plots show the number of individuals for whom the difference between CA and the GP skeletal age estimates differed by more than 2 standard deviations. A study in Dutch published that at ages of 17 years for the male sample and 15 years for the female sample, Greulich and Pyle method became inapplicable (25). These points were at age 16.5 for the male sample and 15.5 for the female sample in the South African population (5,6) . For the current sample from Ethiopia, these points are at ages of 16.5 for the male sample and 16 for the female samples as characterized by the increased number of estimates falling outside of the 2 standard deviation limits.

The underestimation of chronological age by the Greulich and Pyle method by 11.8 months in the female sample and 8.7 months in the male sample reported here can be interpreted as a delay in skeletal maturation in the target subjects compared with Greulich and Pyle's reference population.

A study among Turkish children showed that 78.3% of chronologically 17 years of age and 94.1% of 18 years of age subjects in females attained full skeletal maturity. However, in males, 77.8% of chronologically 18 years of age and 95.7% of chronologically 19 years of age children had reached full skeletal maturity (13). In India, 87.5 % of chronologically 18-19 years of age and 100 % of 19-20 years of age individuals in females showed complete epiphyseal fusion, while in males, 96.5% of the chronologically 19-20 years of age completed epiphyseal closure (26). A study in South Africa reported that individuals, who were both chronologically and skeletally 19 years old, represent only 23% of the 19-year age group. Therefore, 77% of 19-year-old individuals had not yet attained skeletal maturity in males and

in females 50 % of chronologically 17 and 67% of 18 has attained maturity. They also reported that in more than three quarters of each sample, CA was under estimated with recording scores of 78.1% and 74.0% for the female and male samples, respectively (5,6).

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