Association between chronological and skeletal ages among a sample of Saudi male children

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يعتبر تحديد مدى النمو الهيكلي من أهم سمات العمل السريري في مجال تقويم الأسنان وغيره من التخصصات الصحية. تهدف هذه الدراسة إلى ايجاد العلاقة بين العمر الزمني والعمر الهيكلي عند عينة مختارة من الأطفال السعوديين ومقارنة معدل نموهم الهيكلي بنظائرهم من مجموعات عرقية مختلفة. شارك في هذه الدراسة ١١٥ طفلا سعوديا تم تحديد عمرهم الهيكلي بإستخدام الأشعة السينية لكف اليد، كما تم أيضا تحديد مرحلة النمو الهيكلي لكل مشارك بطريقة بيورك. وجرى بعد ذلك دراسة العلاقة الاحصائية بين متوسط العمر الزمني و الهيكلي خلال مراحل النمو الهيكلي المختلفة، بالإضافة إلى ذلك تمت مقارنة العينة السعودية المدروسة بالمجموعات العرقية الأخرى. أظهرت نتائج هذه الدراسة تأخر النضوج عند العينة المختارة من الأطفال السعوديين حيث كان معدل متوسط العمر الهيكلي أقل بشكل جوهري ($p<0.05$) عن العمر الزمني خلال مراحل النمو الهيكلي المختلفة التي تم دراستها. أما في ما يتعلق بمعدل النموالهيكلي لدى العينة السعودية المدروسة، فقد بينت نتائج الدراسة أن هذا المعدل مقارب لمثيله لدى العينات العرقية الأخرى. تعتبر نتائج هذه الدراسة ذات فائدة في تشخيص ومعالجة الكثير من الحالات في مجال تقويم الأسنان وطب أسنان الأطفال وغيرهما من المجالات الصحية الأخرى.

Assessment of skeletal maturity is a necessary clinical need in orthodontics and other health professions. **OBJECTIVE:** The aim of this study was to detect the association between chronological age and skeletal age in a selected Saudi male sample and to compare their skeletal maturity rate with other populations. **MATERIALS and METHODS:** Hand-wrist radiographs were obtained for 115 subjects and the skeletal age for each subject was determined using a standard hand-wrist radiographic atlas. Also, the skeletal maturity stage for each subject was established using Björk assessment method. Statistical tests were performed to detect significant differences between chronological and skeletal ages at different skeletal maturity stages. The rate of skeletal maturity of the participating Saudi sample was also compared to analogous values that were previously established for other populations. **RESULTS:** The findings of the present study indicated that the participating Saudi children had a tendency towards late maturation with the mean skeletal age of the participating subjects being significantly lower ($P<0.05$) than the chronological age at various skeletal maturity stages. When considering the rate of skeletal maturity, the participating Saudi children demonstrated a comparable maturity rate to that of other children from different populations. The results of the present study could enhance the diagnosis and treatment planning in orthodontics, pedodontics, and other health disciplines.

INTRODUCTION AND REVIEW LITERATURE

The clinical need for assessment of physical maturation has significant implications for many health professions. Despite the differences among professional health disciplines, appropriate determination of an individual's status of physical maturity could have direct implications on the diagnosis, treatment planning, and the ultimate disease treatment outcomes.

Assessment of physical maturation can be based on any of a number of developmental markers such as somatic, mental, behavioral, reading, dental, and skeletal maturity indicators.[1-3] For example, somatic maturation is recognized by peak growth velocity in body height and/or weight.[4,5] Skeletal maturity, on the other hand, is reflected by changes of secondary sex characteristics and voice changes in boys and menarche in girls. However, the usefulness of somatic and sexual maturity indicators has limited clinical value due to the fact that they can only be applied after serial registration

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of height and/or weight or the inception of puberty.[6] The retrospective nature of examining the individual's maximum growth period with the somatic and sexual maturity indicators disregards many clinical interests for forecasting the onset of the growth peak, rather than learning after the fact, to maximize the treatment potential of some treatment modalities.[7,8]

Generally, chronological age is considered a poor indicator for estimating the degree of skeletal maturity due to significant individual growth variations among children of the same chronological or calendar age groups.[9-12] On the other hand, significant association between the level of skeletal maturity and general biologic and physiologic maturation was observed.[1,13,14]

Hand-wrist radiograph has long been used to indicate the stage of skeletal maturity and predict the onset of maximum pubertal growth.[15-18] The coexistence of large number of bony structures with distinct and yet predictable sequence of maturation has made hand-wrist radiographs a useful clinical tool to assess the overall skeletal maturation. By comparing the hand-wrist radiograph of a patient with standard hand-wrist radiographic images of an atlas,[19] the clinician can determine the skeletal age of the patient. Also, the availability of established hand-wrist analyses of Björk[16] and Fishman[20], which divides the maturation process of bones of the hand and wrist into multiple and progressive developmental stages, has facilitated the use of hand-wrist radiographs in clinical orthodontics to estimate the maximum growth potential and thus plan for growth modification modality to coincide with the most rapid growth period.

Previous investigations have established a relationship between the chronological age and the degree of skeletal maturity for several populations.[20-22] Nonetheless, the relationship between the chronological age and the stage of skeletal maturation for Saudi population has not been determined. The establishment of such relationship for Saudi children will reflect upon the daily practice of many health professionals in Saudi Arabia. For example, clinical decisions concerning the growth modification intervention to correct some dentofacial skeletal discrepancies will benefit from learning whether the Saudi children are late or early maturers with respect to their chronological ages. In general, health professionals who are concerned with the level of skeletal maturity may find it useful to establish the relationship between the skeletal age and the chronological age in order to estimate whether Saudi male children tend to be early or late skeletal maturers.

The purpose of this study was to detect the association between the chronological age and the stage of skeletal maturity of participating Saudi male children based on their hand-wrist radiographs and to compare their rate and attainment of skeletal maturity with established rates for children from three different populations.

MATERIALS AND METHODS

The sample consisted of 115 hand-wrist radiographs of the left hand obtained from male children attending the clinics of College of Dentistry, King Saud University, Riyadh, Saudi Arabia. The selection criteria for this study were that all children must (1) be Saudi males with age ranges from 9 to 15 years; (2) have normal growth and developmental conditions; (3) be free of any serious illness; and (4) have no previous history of diseases or trauma to the hand and wrist area.

The skeletal age for each subject was established from the hand-wrist radiograph using the radiographic atlas of skeletal development of hand and wrist by Greulich and Pyle.[19] The stage of skeletal maturity for each subject was determined according to Björk method.[16] However, to promote an easy and distinct discrimination between the stages and to provide a good description relative to the growth position, only 6 skeletal maturity indicators were selected in the present study. As has been established by Björk[16] and by Fishman[23], significant estimation of growth status can be accomplished by such skeletal maturity stages. The PP_2 stage becomes visible well-ahead (about 2 years) of the adolescent growth peak. The MP_3 stage usually appears during the onset of accelerating growth period towards the peak. The S and the MP_{3cap} stages frequently are seen during a period of very rapid growth velocity. The DP_{3u} and MP_{3u} stages typically coincide with the time period of decelerating growth rate.

The following ossification events were assessed:

- **PP_2** stage: when the epiphysis of proximal phalanx of the second finger (index finger) has the same width as the diaphysis.
- **MP_3** stage: when the epiphysis of the middle phalanx of the third finger has the same width as the diaphysis.
- **S** stage: when the mineralization of the ulnar sesamoid bone of the adductor brevis muscle at the metacarpophalangeal joint of the thumb is first apparent.
- **MP_{3cap}**: when the diaphysis of the middle phalanx of the third finger is covered by the cap-shaped epiphysis.
- **DP_{3u}**: when visible union of epiphysis and diaphysis of the distal phalanx of the third finger can be seen.
- **MP_{3u}**: when visible union of epiphysis and diaphysis of the middle phalanx of the third finger can be seen.

All assessments were carried out simultaneously on an illuminated viewing box in a dark room by one experienced examiner. Chronological age for each subject was verified by referring to the provided personal information of the patient. All hand-wrist radiographs were obtained at the same day that the chronological age of each subject was recorded. All subjects were informed about the nature of the study and a letter of consent was obtained.

STATISTICAL ANALYSIS

Statistical tests were performed using the SPSS software package (Version 12, SPSS Inc., Chicago, IL, USA), unless otherwise indicated. To test the intra-examiner reliability of radiographic assessments, the same examiner re-evaluated randomly selected fifty hand-wrist radiographs two weeks after the first evaluation. In addition, the correlation between the readings of the main examiner and another experienced examiner was evaluated by assessing fifty randomly selected hand-wrist radiographs to test the inter-examiner reliability.

Descriptive statistics were obtained by calculating the means and standard deviations for the combined sample and for chronological ages at different stages of skeletal maturity. The correlation coefficient and paired-sample t-tests were used to evaluate the correlation between corresponding data and to detect significant differences between means, respectively.

In order to compare the means of chronological age at various skeletal maturity stages among samples from different populations, GraphPad Prism software (GraphPad version 4, GraphPad Software, Inc., San Diego, CA, USA)

was used to evaluate the statistical significance of any differences, taking into consideration the mean, the standard deviation, and the sample number for each group.

RESULTS

The sample consisted of 115 male subjects whose ages ranged from 9 years to 15 years. The distribution of the study subjects according to the chronological age and the skeletal maturity stage is presented in Table 1 and Table 2, respectively. The mean chronological age was found to be 12.16 ± 1.47 (mean ± SD) and the mean skeletal age was 11.44 ± 1.83 (mean ± SD).

The chronological and skeletal age readings were found to be highly correlated (r value = 0.80). The reliability of intra-examiner and inter-examiner radiographic interpretation was found to high as evidenced by the high correlation between readings recorded at different time points by the main examiner and readings recorded by the two different examiners, respectively (Table 3).

The mean skeletal age was found to be lower and significantly different (P<0.05) from the mean chronological age at all skeletal maturity stages except at the $MP3_{cap}$ stage where no significant difference was detected (Figure 1). Similarly, the mean skeletal age was found to be constantly and significantly (P <0.05) lower when compared with the chronological age except at 9 and 15 years of chronological age (Figure 2).

When the mean chronological age of the present Saudi sample was compared with the chronological age of different racial groups at the six selected maturation stage, it was observed that the Saudi children were closely related (within each skeletal maturity stage) to their matching

Table 1. Sample distribution among the different chronological age groups.

	Chronological Age*						
	9 Y	10 Y	11 Y	12 Y	13 Y	14 Y	15Y
N	1	17	22	29	21	19	6
Percentage	1%	15%	19%	25%	18%	17%	6%

* Mean chronological age ± SD = 12.16 ± 1.47

Table 2. Sample distribution among the different skeletal maturity stage groups.

	Skeletal Maturity Stage					
	PP_2	MP_3	S	MP_{3cap}	DP_{3u}	MP_{3u}
N	29	41	12	12	11	10
Percentage	25%	36%	10%	10%	10%	9%

Table 3. Correlation coefficient for intra-examiner and inter-examiner reliability.

	N	Correlation	Sig.
Examiner A X Examiner A - 2 Weeks	50	0.920	0.000
Examiner A X Examiner B	50	0.932	0.000

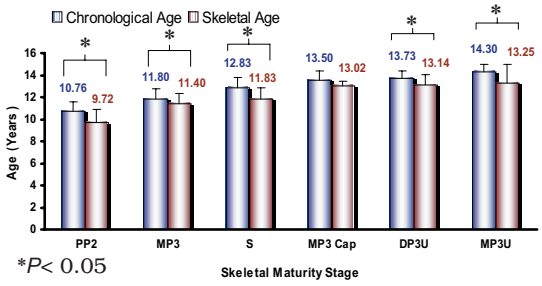

Fig. 1. The mean chronological age and the mean skeletal age at different skeletal maturity stages.

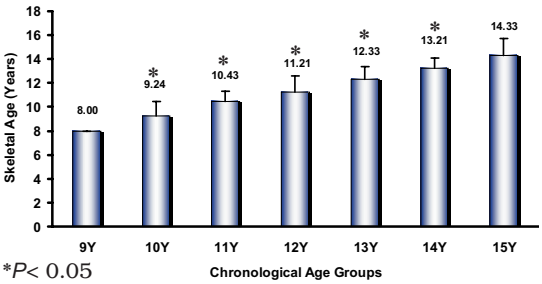

Fig. 2. The mean skeletal age corresponding to each chronological age group (r-value = 0.80).

peers among other racial groups (Figure 3). The only statistically significant differences were detected between the Saudi sample and the Thai sample at the MP_3 stage (P <0.05) and S stage (P <0.01) and also between the Saudi children and the Turkish children at the DP_{3u} stage (P <0.01) as shown in Figure 3.

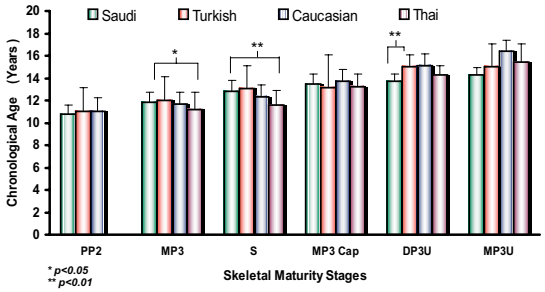

Fig. 3. The mean chronological age for different population samples at various skeletal maturity stages.

DISCUSSION

Hand-wrist radiograph has long been used to indicate the stage of skeletal maturity and predict the onset of maximum pubertal growth.[15-18] The skeletal age for each subject was assessed using hand-wrist radiograph according to the method outlined in the radiographic atlas of skeletal development of hand and wrist.[19] This method is well-established and is known for its simplicity and practicality because it is relatively easy to learn and perform.[24] The atlas method has been found to be less time-consuming; less complicated, and has a greater reproducibility between observers.[25] However, it is essential to recognize the differences between the local population and the reference population used to define the standards in the atlas.

The ideal situation is to use standard plates calibrated for each local population. Nonetheless, the wide use of the Greulich and Pyle atlas method[19] in several previous investigations for distinct populations justified its application to make a comparison between the local Saudi population and different population samples, all of which have been evaluated against Greulich and Pyle's standard hand-wrist plates.

In the present study, the assessment of the skeletal maturity stage was based on Björk method.[16] Closely related to the skeletal maturity indicators established by Fishman,[20,26] the Björk system offers an organized and relatively simple approach to determine the level of skeletal maturation from the hand-wrist radiograph. Björk utilized certain anatomical sites located on the phalanges and the adductor sesamoid which have predictable and consistent time of onset of ossification.[16] Also, it is an advantage of this method to exclude the carpal bones from the system since irregularity in the order of onset of ossification occurs more frequently in the carpal than in the metacarpal or phalangeal epiphyses.[19] For these reasons and for the fact that most of the related local clinical practitioners here in Saudi Arabia are more familiar with this method, Björk classification method was utilized for the present study.

The distribution of the sample in the present study among the different chronological age categories as presented in Table 1 shows fair distribution of the sample among various categories except for the 9-years group which had only one subject. Thus, results related to this group should be considered with caution until sample size in this category is increased in future studies. On the other hand, Table 2 demonstrates reasonable distribution of the study sample among different skeletal maturity stages. The latter pattern of sample distribution is consistent with the previous studies performed on other populations such as Thai[21] and Turkish[22].

The simplicity of the atlas method[19] and the use of distinct and clear skeletal maturity indicators perhaps contributed

to the high reproducibility of the readings in this study as demonstrated by the high correlation coefficient values in Table 3. The mean skeletal age was found to be constantly lower than the mean chronological age at all skeletal maturity stages (Figure 1). Similar finding has been previously reported among Thai and Turkish samples.[21,22] In addition, the difference between the mean skeletal age and the mean chronological age was found to be statistically significant ($P<0.05$) at all skeletal maturity groups except at MP_{3cap} stage. Individual variability at this particular maturity stage is a possible contributory factor for such inconsistent finding.

In contrast to the reported Thai result,[21] the mean skeletal age was shown to be constantly lower, by at least few months, than the chronological age (Figure 2). This finding indicates that the Saudi children tend to be late maturers when chronological age is used to indicate the skeletal maturity, whereas the Thai children have the tendency to mature skeletally at an earlier chronological age.[21] However, the dissimilarity in racial and environmental aspects could explain such contrast in this finding. In addition, the mean chronological age of the Saudi sample at different skeletal maturity stages was demonstrated to be in close association with reported values among other racial groups (Figure 3). Nonetheless, at the MP_3 and S stages of skeletal maturity, a significant ($P<0.05$) difference was detected between the mean chronological age of the Saudi children and the Thai children (Figure 3). Likewise, significant ($P<0.05$) difference was demonstrated between the mean chronological age of the Saudi sample and the Turkish sample at the DP_{3u} stage (Figure 3). So, the Saudi children seem to be reaching the pre-pubertal skeletal stages later than the Thai children. However, this difference tends to flattens out during the deceleration phase after the growth peak.

In general, the differences reported in the present study in relating the mean chronological age to the skeletal maturity stage for samples from different populations can be attributed to differential racial backgrounds, distinct environmental conditions, and/or some research methodology disparity associated with the sample size and/or sample distribution.

CONCLUSION

The findings of the present study indicated that the participating Saudi children have a tendency towards late maturation with the mean skeletal age of the participating subjects being significantly lower ($P<0.05$) than the chronological age at various skeletal maturity stages. When considering the rate of skeletal maturity, the participating Saudi children demonstrated a comparable maturity rate to other children from different populations. The results of the present study can enhance the diagnosis and treatment planning for orthodontists, pedodontists, as well as many other health disciplines. Further studies are inevitable by increasing the sample size and by improving the sample distribution among the various regions of Saudi Arabia. The more representative sample will help to establish distinct maturity standards for the Saudi population.

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