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Original Article

Dentistry Section

Association between Body Mass Index, age at Menarche with Skeletal Maturity Indicators using Hand Wrist Radiograph in Bengali Female Population: A Cross-sectional Study

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ABSTRACT

Introduction: Estimation and use of craniofacial growth is crucial in addressing skeletal discrepancies for orthodontic correction of young and growing children. It is crucial to determine each patient's skeletal age and compare it to their dental and chronological ages before diagnosing a proper treatment plan. An essential biological indicator for determining a female's physiologic maturity is her age at puberty. Menarche and hand wrist skeletal maturation can be used to determine the beginning and conclusion of the pubertal growth spurt.

Aim: To find association between Body Mass Index (BMI), age at menarche with hand-wrist radiograph in Bengali female population.

Materials and Methods: The present cross-sectional study was conducted at Department of Orthodontics and Dentofacial Orthopaedics in collaboration with the Department of Pedodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, India from March 2022 to January 2024. Hundred subjects were evaluated in the age range of 9-15 years. Subjects' menarcheal age, BMI and Skeletal Maturity Indicators (SMI) using hand wrist X-ray were assessed and tabulated. Statistical analysis was done to find association between these three parameters. (GraphPad Prism Software version 9.5, La-Jolla, California) was used for analysis. Parametric tests, One-way Analysis of Variance (ANOVA), Post-hoc Tukey's and Chi-square (χ^2) test were used for inferential statistics.

Results: The mean menarche age of subjects were 12.2±1.2 years. It was observed that obese girls had the onset of menarche at an early stage (10.06±0.35 years), followed by overweight girls (11.15±0.72 years), normal weight girls (12.73±0.68 years), and then underweight girls who had their menarche at 14.2±0.14 years; p<0.001*. Higher skeletal maturity (stage VII, VIII), 40%, 42.5%, respectively was achieved only at higher age groups and was dependent on the age at menarche (p<0.001**). BMI showed an inverse association to skeletal maturity. Subjects with healthy BMI (healthy) showed good skeletal maturation rate.

Conclusion: Obese girls experienced menstruation earlier as compared to healthy and underweight girls. Data indicated that menarche and BMI percentile were inversely associated. Significant statistical relation was seen in between the BMI percentile and the SMI and between peak pubertal growth assessed by hand-wrist X-ray as SMI and the menarche onset.

Keywords: Chronological age, Female, Growth indicators, Obese, Puberty, Skeletal age

INTRODUCTION

Craniofacial growth is crucial in evaluation of skeletal discrepancies for orthodontic correction of young and growing children [1]. Determining the beginning, acceleration, maturation, and cessation of growth is essential for the effectiveness of the early orthodontics and orthopaedic therapy [2-4]. However, each person's growth process varies in terms of time, duration, and speed. Variation in pubertal growth spurt is influenced by various factors like chronological age, sex, family trends, social and economic status, ethnic factors, race etc., [3]. It is crucial to determine each patient's skeletal age and compare it to their dental and chronological ages before formulating a proper treatment plan [4-7]. Hand-wrist radiography is used to identify skeletal age with great precision [2-4]. Several biological markers have been used for evaluation each person's physiologic maturity, These include reaching a higher body height, developing breasts, pubertal markers (male and female voice changes, attainment of puberty, pubic or axillary hair appearance in adolescents), teeth eruption sequences, maturation status using SMI and cervical vertebrae maturity indicator level [8]. There is a growing need for intraoral or panoramic radiography to evaluate dental growth [8]. An essential biological indicator for determining a female's physiologic maturity is her age at menarche that can be easily recalled. Many studies have looked into the connection between the start of puberty and the body height growth spurt. Menarche and hand-wrist skeletal maturation could be used to determine the beginning of growth spurt [9-13]. The onset of menarche in young girls may be used for a prompt clinical assessment of general and facial growth without using radiography [9]. Several researchers found a correlation between skeletal maturation and age at puberty and BMI separately in different racial populations [10-12]. Modern lifestyles, food habits, and improved socio-economic status have resulted in a change in the mean pubertal age of the Indian female population [13].

The present study aimed to investigate the relationship between BMI, skeletal maturation, and onset of menarche in growing Bengali girls.

MATERIALS AND METHODS

The present cross-sectional observational study was done in the Department of Orthodontics and Dentofacial Orthopaedics and the Department of Pedodontics, Guru Nanak Institute of Dental Sciences and Research, Kolkata, India from March 2022 to January 2024 after obtaining ethical clearance (vide IEC no- GNIDSR/IEC/21-24/18).

Radiographs of the hands and wrists were obtained from patients, aged 9-15 years, who reported for orthodontic correction.

Sample size calculation: The size of the sample was calculated by G* Power software (V-3.1.9.7, University Duesseldorf, Germany). With an Alpha value of 0.05 and a power of 80% were included in the study. The final sample size was calculated as 100 (N=100).

Inclusion criteria: Female subjects in the age group between 9 and 15 years of Bengali ancestry (West Bengal, India) were evaluated. The subjects attaining menarche within six months before the date of data collection.

Exclusion criteria: Subjects having endocrine disorders, congenital anomalies (cleft lip and palate) and any previous history of orthodontic treatment (myofunctional appliances, headgear etc.,) and orthognathic surgery were excluded.

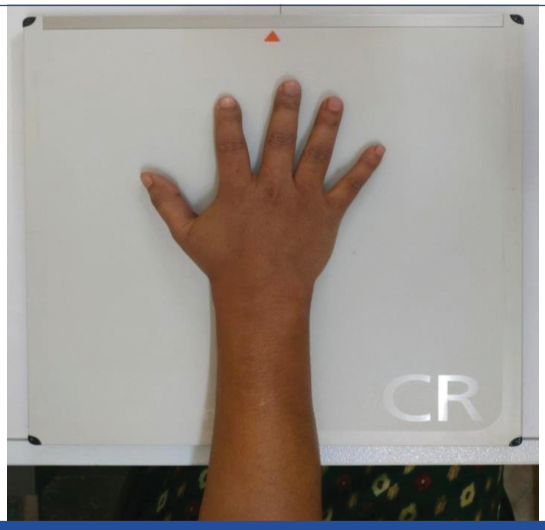
Study Procedure

There were three components to the data collection:

Details on menarche: The female patients who reported to the department of orthodontics and dentofacial orthopaedics and department of pedodontics and preventive dentistry of Guru Nanak Institute of Dental Sciences and research in Kolkata were asked to recall the month of their menarche in order to record menarcheal information. Their parents, who were with them, also verified the same. Using each patient's birth month and menarche date, the age at menarche was computed in years and months.

Hand wrist radiograph: Hand wrist radiograph of the selected subjects were taken from the Department of Oral Radiology.

The hand wrist X-rays were taken using X-tech hf X-ray frequency 80 khz Focal Spot-0.5×0.5 mm (According to IEC336), Filtration 2.5 mm AL, Gray Scale-14 bit, Exposure time-12.9 sec line voltage and current-125 kVp and 300 mA Film size-8×10 inch [Table/Fig-1,2].



[Table/Fig-1]: Hand position in X-ray cassette.

SMI using hand wrist X-ray (Fishman Method) were assessed [14].

BMI index: Raw BMI values using weight and height information was calculated. BMI was computed as follows: mass (kg)/{height $(m)^2$}, where weight was divided by height squared [Table/Fig-3,4].

Plotting height, weight, and age at menarche were also done. Each patient's raw BMI score on the x-axis and age at menarche on the y-axis on Indian Academy of Paediatrics (IAP) girl's BMI charts allowed for the calculation of each subject's BMI percentile value. For descriptive purposes, the designated BMI groupings were as follows: Less than the third percentile of the BMI indicates underweight, between the third and 74th percentiles, normal weight, between the 75th and 89th percentiles, overweight, and over the 90th percentile, obesity. Using an interview on onset of menarche, all of the information was gathered [Table/Fig-5]. All information was entered into a single computerised spreadsheet.

[Table/Fig-2]: Handwrist X-ray.

[Table/Fig-3]: Height was measured by using height measuring scale (Stadiometer) (brand name Beatx).

[Table/Fig-4]: Weight was measured by digital Weighing scale scale.

STATISTICAL ANALYSIS

Microsoft Excel 2019 was used to tabulate the obtained data in a spreadsheet, (GraphPad Prism Software version 9.5, La-Jolla,

[Table/Fig-5]: Participants asked about menarcheal history and filling up of consent form for this study.

California) was used. Descriptive statistics were used to report-categorical variables in terms of frequencies and percentage.

Quantitative variables were reported as mean and standard deviation. Inferential statistics were tested using parametric tests, One-way ANOVA, Chi-square (χ^2) test and post-hoc Tukey's HSD test were employed for measuring the differences between groups for the various outcome variables.

RESULTS

The mean age of the sample was 12.41±1.41 years. [Table/Fig-6] depicts that maximum subjects (n=25) belongs in the age group of 12-13.9 years. [Table/Fig-7] shows the mean menarche age of subjects were 12.2±1.2 years. [Table/Fig-8] shows the mean height, weight and BMI of the subjects. Maximum subjects (n=40) had a height of 152.5±2.26 cm, weight of 42±1.74 kg and BMI 18.16±0.82 kg/m^2.

Age group (years)	N
<11	17
11-11.9	16
12-12.9	27
13-13.9	25
14-14.9	15
Mean±SD age	12.41±1.41

[Table/Fig-6]: Distribution of the study subjects according to the present age (in years).
n: No. of subjects per age group

Age of menarche (years)	N
<11	17
11-11.9	17
12-12.9	40
13-13.9	22
14-14.9	4
Mean±SD age of menarche	12.2±1.2

[Table/Fig-7]: Distribution of the study subjects according to the age of menarche (in years).
n: No. of subjects per age group

Age at menarche (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
<11 (n=17)	136.24±1.35	42.29±2.11	22.72±1.17
11-11.9 (n=17)	144.41±5.73	41.94±1.71	20.29±1.89
12-12.9 (n=40)	152.25±2.26	42±1.74	18.16±0.82
13-13.9 (n=22)	152.59±2.11	36.95±2.54	15.85±1.01
14-14.9 (n=4)	119±69.35	32.75±2.06	14.03±0.5
Total (N=100)	146.94±15	40.56±3.3	18.62±2.7

[Table/Fig-8]: Mean height (cm), weight (kg) and BMI for various age groups (at menarche) included in the study.

Study showed that the majority of the subjects belonged to healthy (66) BMI category [Table/Fig-9]. Obese girls had the onset of menarche at an early stage (10.06±0.35 years), followed by overweight (11.15±0.72 years) then healthy girls (12.73±0.68 years), whilst the underweight girls had their menarche at 14.2±0.14 years p<0.001** [Table/Fig-10]. [Table/Fig-11] shows the pair wise comparisons between mean age at menarche according to the different BMI status. In the study, the majority of the study subjects were at Stage VIII of skeletal maturity (27%) which [Table/Fig-12].

BMI category	N
Underweight	4
Healthy	66
Overweight	20
Obese	10

[Table/Fig-9]: Distribution of the study subjects according to the Body Mass Index (BMI) status (n=100).
n: No. of subjects per BMI status

	Underweight (n=4)	Healthy (n=66)	Overweight (n=20)	Obese (n=10)	p-value
Mean age at menarche (in years)	14.2±0.14	12.73±0.68	11.15±0.72	10.06±0.35	<0.0001**

[Table/Fig-10]: Comparison of the mean age at menarche (in years) between the different BMI groups (n=100).
ANOVA

Tukey's multiple comparisons test	Mean Diff.	Adjusted p-value
Underweight vs. healthy	1.471	0.002*
Underweight vs. overweight	3.050	<0.001**
Underweight vs. obese	4.140	<0.001**
Healthy vs. overweight	1.579	<0.001**
Healthy vs. obese	2.669	<0.001**
Overweight vs. obese	1.090	0.0002*

[Table/Fig-11]: Pair wise comparisons between mean age at menarche according to BMI status.
*: statistically significant (p≤0.05); **Highly significant

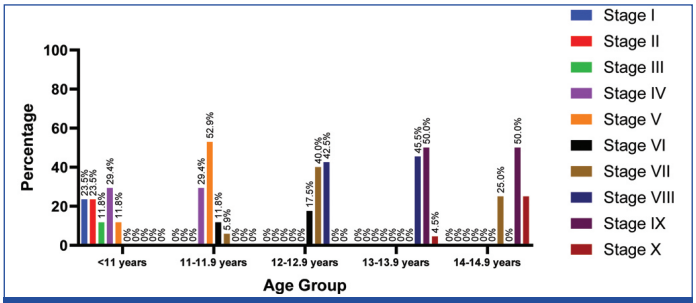
SMI	n (%)
Stage I	4 (4%)
Stage II	4 (4%)
Stage III	2 (2%)
Stage IV	10 (10%)
Stage V	11 (11%)
Stage VI	9 (9%)
Stage VII	17 (17%)
Stage VIII	27 (27%)
Stage IX	13 (13%)
Stage X	3 (3%)

[Table/Fig-12]: Distribution of the study subjects according to the stages of Skeletal Maturity Indicators (SMI) [14].
SMI stage VIII signifies fusion of epiphysis and diaphysis in distal phalanx of middle finger [14]

A corrected Chi-square (χ^2) test implies that skeletal maturity was achieved only at higher age groups and was age-dependent i.e., higher skeletal maturity (stage VII, VIII), 40%, 42.5% respectively was achieved in the age group (12-12.9 years) (p<0.001). For age 13-15 years the majority of the subjects belong in stage IX [Table/Fig-13]. [Table/Fig-14] shows the distribution of the stages of skeletal maturity index according to the age at menarche (in years). It was observed that the majority of the underweight girls belonged to either Stage IX (2, 50%). Girls with healthy BMI majorly belonged to Stage VIII (25, 37.9%) followed by Stage VII (17, 25.8%). Overweight girls belonged in Stage IV (9, 45%) and obese girls in Stage I (4, 40%). The p-value, p<0.001** [Table/Fig-15].

SMI	<11 y (n=17)	11-11.9 y (n=17)	12-12.9 y (n=40)	13-13.9 y (n=22)	14-14.9 y (n=4)	Total (N=100)
Stage I	4 (23.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (4%)
Stage II	4 (23.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (4%)
Stage III	2 (11.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (2%)
Stage IV	5 (29.4%)	5 (29.4%)	0 (0%)	0 (0%)	0 (0%)	10 (10%)
Stage V	2 (11.8%)	9 (52.9%)	0 (0%)	0 (0%)	0 (0%)	11 (11%)
Stage VI	0 (0%)	2 (11.8%)	7 (17.5%)	0 (0%)	0 (0%)	9 (9%)
Stage VII	0 (0%)	1 (5.9%)	16 (40%)	0 (0%)	1 (25%)	18 (18%)
Stage VIII	0 (0%)	0 (0%)	17 (42.5%)	10 (45.5%)	0 (0%)	27 (27%)
Stage IX	0 (0%)	0 (0%)	0 (0%)	11 (50%)	2 (50%)	13 (13%)
Stage X	0 (0%)	0 (0%)	0 (0%)	1 (4.5%)	1 (25%)	2 (2%)

[Table/Fig-13]: Distribution of the stages of skeletal maturity index according to the age at menarche (in years).

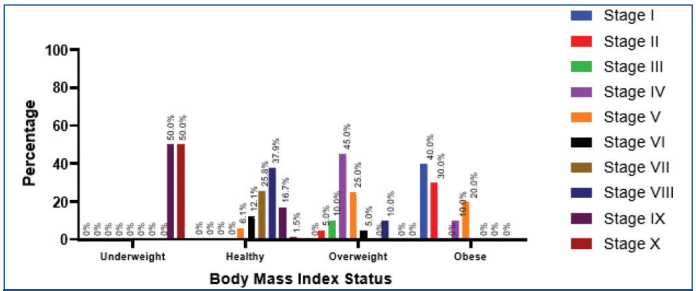


[Table/Fig-14]: Bar graph: distribution of the stages of skeletal maturity index according to the age at menarche (in years).

SMI	Underweight (n=4)	Healthy (n=66)	Overweight (n=20)	Obese (n=10)	Total (N=100)
Stage I	0 (0%)	0 (0%)	0 (0%)	4 (40%)	4 (4%)
Stage II	0 (0%)	0 (0%)	1 (5%)	3 (30%)	4 (4%)
Stage III	0 (0%)	0 (0%)	2 (10%)	0 (0%)	2 (2%)
Stage IV	0 (0%)	0 (0%)	9 (45%)	1 (10%)	10 (10%)
Stage V	0 (0%)	4 (6.1%)	5 (25%)	2 (20%)	11 (11%)
Stage VI	0 (0%)	8 (12.1%)	1 (5%)	0 (0%)	9 (9%)
Stage VII	1 (25%)	17 (25.8%)	0 (0%)	0 (0%)	18 (18%)
Stage VIII	0 (0%)	25 (37.9%)	2 (10%)	0 (0%)	27 (27%)
Stage IX	2 (50%)	11 (16.7%)	0 (0%)	0 (0%)	13 (13%)
Stage X	1 (25%)	1 (1.5%)	0 (0%)	0 (0%)	2 (2%)

[Table/Fig-15]: Distribution of the stages of skeletal maturity index according to the BMI status.
This table indicated that BMI has a direct inverse association to skeletal maturity. Subjects with BMI at normal range (Healthy) showed a good skeletal maturation rate

[Table/Fig-16] shows the distribution of stages of skeletal maturity according to BMI status.



[Table/Fig-16]: Bar graph showing distribution of the stages of skeletal maturity index according to the BMI status.

DISCUSSION

The study aimed to find out if any association exists between BMI, age at menarche with hand wrist radiograph in young Bengali female population.

The present study attempted to study the association between BMI with SMI staging in our study. The staging of SMI varied significantly throughout BMI categories. This suggested a relationship exists between SMI and BMI and that SMI is influenced by BMI.

Hassel B and Farman AG stated that SMI represents the whole percentage of skeletal growth anticipated in a person and this is consequently influenced by overall health or BMI [15]. The majority of girls in the underweight group in this study were identified in Stage IX of SMI staging, while the highest number of obese girls were found to be in Stage III $p<0.05$.

Similarly, as compared to underweight females, obese girls had greater skeletal growth remaining at the commencement of menarche even if they had reached sexual maturity earlier. Vichare GS et al., conducted a study in which they assessed the association between different maturity markers during adolescence in Maharashtrian females and discovered a direct correlation between Cervical Maturity Indicator and SMI and chronological age, as well as BMI at all stages $p<0.001$ [16].

Lai EH et al., evaluated the relationship between skeletal maturation and menarche age in female orthodontic patients and found that more than 90 percent of patient who have attained menarche were in the SMI stages of VI, VII and VIII [3]. Understanding a growing patient's skeletal maturity is crucial prior to orthodontic treatment planning. Two commonly utilised methods for this purpose are Cervical Vertebrae Maturity Indicators (CVMI) and SMI staging, which predict growth mandible, and overall skeletal growth respectively. Additional onset of menarche is often employed in orthodontics to anticipate skeletal maturity. It's commonly believed that minimal skeletal growth, particularly mandibular growth, remains after menarche onset. However, the present study findings revealed that there was association between menarche and skeletal maturity, indicating that these processes occur independently. Orthodontists should exercise caution when assessing skeletal maturity based solely on sexual maturity indicators such as menarche. This study findings supports the notion that BMI, a measure of overall health, has an impact on menarche. Lai EH et al., evaluated the relationship between the age at menarche and skeletal maturation in female orthodontic patients and stated that >90% of the 148 subjects who had already attained menstruation had skeletal maturation SMI VI, VII, VIII, and on average, menarche occurred between SMI Stages [3]. The relationship between age at menarche and socioeconomic status investigated in India by Vijayalakshmi S and Chandrababu R revealed that the mean menarcheal age steadily decreased with the increase in per capita income [17].

Limitation(s)

For a better outcome, a larger sample size is needed. CVMI can be added to handwrist radiograph for more precision outcome. Other ethnic groups can be studied to generalise the outcome of this particular study.

CONCLUSION(S)

Obese girls experienced earlier menstruation as compared to healthy and underweight girls Significant statistical relation was seen between the BMI and the SMI in the subjects. Depending on the BMI index, same-aged girls were at different SMI stages. In terms of overall skeletal growth, obese girls became skeletally less mature. Orthodontic treatment planning should be done cautiously because the onset of menarche and skeletal maturity are two distinct events.

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