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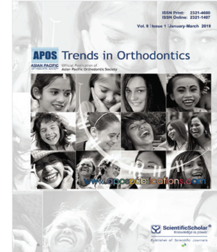

*Original Article*

# Relationship between age at menarche, body mass index percentile, and skeletal maturity stages in Indian female orthodontic patients

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## ABSTRACT

**Introduction:** Skeletal maturity is of paramount importance for the diagnosis and prognosis of orthodontic treatment undertaken in adolescents. This can be assessed by different methods. The study here aims at evaluation of the effect of the onset of menarche and body mass index (BMI) percentile, i.e., overall body growth, on the skeletal maturation of adolescent females and, to find the relationship between age at menarche, cervical maturation stages, and BMI percentile in female orthodontic patients of Indian origin.

**Materials and Methods:** Adolescent females were asked to fill a questionnaire to extract the history of their menarche and chronological age and those within 3 months of menarche were selected. Their height and weight were measured under standard conditions and BMI was calculated. Lateral cephalograms obtained for them were scaled for cervical vertebrae maturation stages according to Hassel and Farman's method. These parameters were then statistically correlated.

**Results:** The results showed that the girls with higher BMI percentile attained menarche early than their healthier counterparts, whereas attaining menarche did not correlate with any specific stage of skeletal maturity.

**Conclusion:** Young girls coming for orthodontic treatment should be carefully assessed for skeletal maturity, as variable amount of skeletal growth may be left even after attaining menarche.

**Keywords:** Body mass index percentile, Cervical vertebrae maturation index staging, Menarche, Skeletal maturity.

## INTRODUCTION

In orthodontic treatment for adolescents, an important objective is to use the craniofacial growth to aid the treatment of skeletal discrepancies.[1] Identification of periods of onset, acceleration, and cessation of growth, thus, become crucial to the success and efficiency of the treatment.[2-4] On the other hand, every individual has variation in timing, duration, and velocity of growth. The circumpubertal growth spurt is influenced not only by patient age but also by sex, genetics, ethnicity, nutrition, and socioeconomic status. Therefore, it is important to assess skeletal age of every patient and correlate it with the dental and chronologic age of the patient before formulating viable orthodontic treatment plan.[4-7]

The skeletal age can be quite accurately determined by the use of hand wrist radiographs or by the sequential changes in the cervical vertebrae morphology. The methods for the assessment of skeletal maturation with cervical vertebrae have good reliability and can be performed easily as it requires lateral cephalogram which is routinely taken as pre-treatment diagnostic records for orthodontic treatment.[8] These methods

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have been correlated with both statural (height velocity peak) and the mandibular growth spurt along with other levels of growth biomarkers.[9,10]

The general health of a child has considerable influence on the skeletal maturation of the individual. Literature suggests that increased weight and body fat are often associated with precocious puberty while undernutrition results in growth retardation and stunting.[11,12] Age- and sex-specific body mass index (BMI) percentiles offer a quick, non-invasive, and readily accessible method to assess a child's weight status.[13]

Other important events in the growth curve of children are the attainment of secondary sexual characteristics. Hägg and Taranger[5] in their study found that girls attain menarche after the peak of height growth velocity but before the end of their pubertal growth spurt. Older hypothesis postulates that the pre-menarcheal girl is growing toward an appropriate structural status to facilitate reproduction, and the age at which this structural status is attained is closely related to the age at which she attains menarche.[14] The second view was put forward by Frisch and Revelle, Frisch[15,16] who suggested that age at menarche might be related to the attainment of appropriate weight for reproduction rather than appropriate skeletal status. Although heredity is still the main determining factor in puberty, it seems that other factors such as geographical location, nutrition, health, and well-being as well as socioeconomic factors also play an important role.[17] As the age at menarche is an easily recallable event and if the relationship between menarcheal age and skeletal maturation stages is determined, the onset of menarche may serve as an indicator for immediate clinical judgment of the facial growth.

The data available on correlation of cervical maturity with menarcheal age and BMI percentile with skeletal maturation are based on studies conducted on different racial populations. There are vast racial and genetic differences in body physique, skeletal maturation, and in socioeconomic status, nutrition, and overall living conditions between other races and Indian population. As the socioeconomic conditions and lifestyle are changing in the Indian population, the mean menarcheal age has decreased. Thus, the objective of this study was to understand the correlation between BMI percentiles as given in the Indian Association of Paediatrics (IAP) BMI charts for Indian girls,[18] menarcheal age, and skeletal maturation using Hassel and Farman's cervical vertebrae maturity indicator assessment method. Simultaneously, efforts were made to find if and how the menarcheal age and BMI influence the skeletal maturity for Indian adolescent females.

## MATERIALS AND METHODS

For the study, 100 Indian female adolescent subjects were selected, over a span of 2 years from the Department of Orthodontics and Dentofacial Orthopaedics, M. A. Rangoonwala College of Dental Sciences and Research Centre, Pune, Maharashtra, who fit in the inclusion criteria. All the female adolescent patients between the ages of 10–15 years were asked about their menstrual history and patients within 3 months from onset of menses were included in the study while the patients who were prepubertal were told to inform the investigator, once they attain menarche during their ongoing orthodontic treatment.

An informed consent was signed by all the parents/guardians of the candidates.

### Inclusion criteria

The following criteria were included in the study:

1. Age ≥10 and <15.
2. Girls who are within 3 months of the start of their menses.
3. Indian ancestry.
4. No general developmental anomaly.
5. No congenital anomalies of the second, third, and fourth cervical vertebrae.
6. No significant medical history that would affect physical development and growth.
7. No endocrine disorders.

The collection of data was divided into three parts:

### Menarcheal information

Menarcheal information was documented by asking the girls to identify the month of their first period. Most girls provided the month, which was recallable, but not the date of menarche. The age at the onset of the first menstrual period was recorded. The menarcheal status was confirmed by their parents accompanying them.

### Lateral cephalometric radiographic analysis

The lateral cephalograms were taken. The analysis consisted of the visual appraisal of morphologic characteristic of the three cervical vertebrae (C2 - odontoid vertebrae, C3, and C4).

The morphologies of the three cervical vertebrae (C2, C3, and C4) were hand traced by the investigator (SS) and then evaluated by visual inspection which was performed twice. The first evaluation was done once all 100 lateral cephalograms were collected and the second evaluation was done 4 weeks' after the first evaluation. The variables analyzed were the presence or absence of a concavity at the lower border of the body of C2, C3, and C4 and shape of the body of C3 and C4. Four basic shapes were considered: Trapezoid (the superior border is tapered from posterior to anterior); rectangular horizontal (the heights of the posterior and anterior borders are equal; the superior and inferior borders are longer than the anterior and posterior borders); squared (the posterior, superior, anterior, and inferior borders are equal); and rectangular vertical (the posterior and anterior borders are longer than the superior and inferior borders). Digital films were sequenced randomly, and after a 4 weeks washout period, the investigator (SS) analyzed the resequenced films. Assessment of each lateral cephalogram was done and assigned to one of the six stages according to Hassel and Farman's method.

### BMI percentile

Body weight was measured using weighing machine with an accuracy of 0.1 kg, in light clothing and no shoes. The participants' height was measured by a plastic measuring tape attached to a smooth wall. The participants were required to put their legs straight together, keep their arms to their sides, and keep all knees, shoulders, and back head all in the same direction. The ruler was kept touching their head on the top and the measurement was recorded with an accuracy of 0.5 cm. All the measurements were made at the time when lateral cephalogram was taken. Date of birth was ascertained and recorded by self or parental report.

**Table 1:** The distribution of cases studied according to their age at menarche (*n*=100).

| Age at menarche (years) | Number of cases (%) |
|---|---|
| <11.0 | 5 (5.0) |
| 11.0–11.9 | 28 (28.0) |
| 12.0–12.9 | 33 (33.0) |
| 13.0–13.9 | 27 (27.0) |
| 14.0–14.9 | 7 (7.0) |
| Total | 100 (100.0) |

Values are *n* (% of cases)

Raw BMI scores are calculated using height and weight data. BMI was calculated as weight divided by height squared: BMI = mass (kg)/[height (m)]$^2$. Age at menarche in years and months was calculated using date of birth and month of menarche for each patient. The raw BMI score on x-axis and age at menarche on y-axis of each patient were plotted on IAP girls BMI charts for 5–18 years and the BMI percentile value for each subject was obtained (Figure 1). Height and weight were also plotted against age at menarche. BMI percentile categories per designated were as follows for descriptive purpose: Less than the third BMI percentile - underweight, third to 74th percentile - normal weight, 75th–89th percentile - overweight, and greater than the 90th percentile - obese.

All the information was obtained with the help of an interview on a questionnaire pamphlet. All data were recorded in one electronic spreadsheet.

### Statistical analysis

The data on qualitative characteristics are shown as n (% of cases) and the data on quantitative characteristics are presented as mean ± standard deviation (SD). The statistical significance of the equality of the distribution of several qualitative characteristics is tested

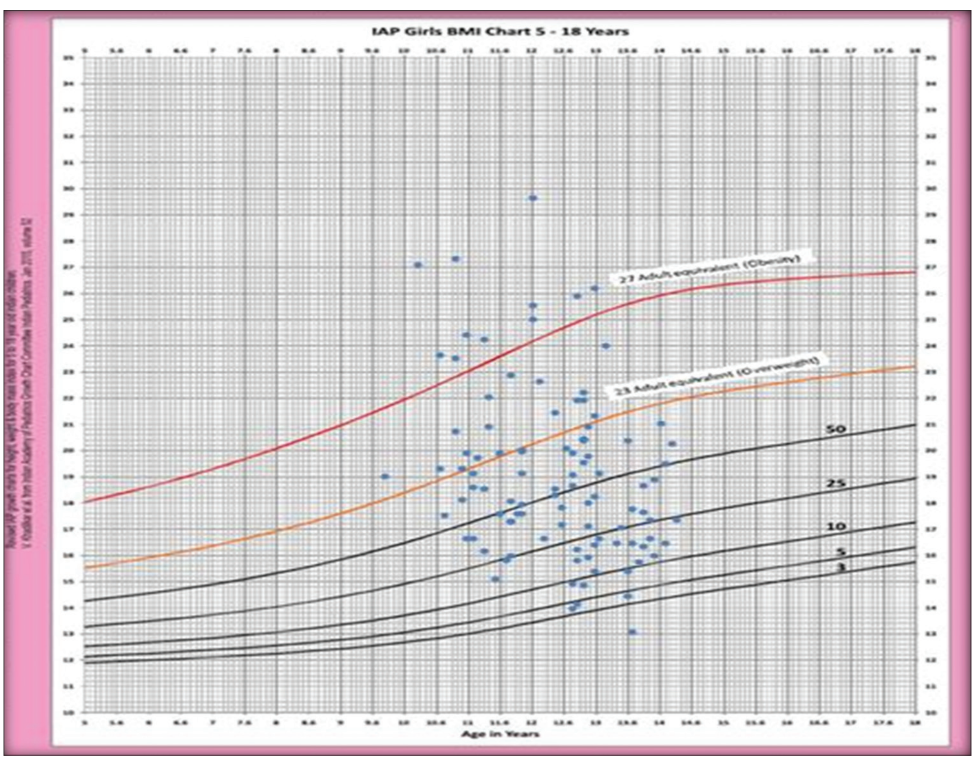


**Figure 1:** Body mass index (BMI) distribution of the sample in the Indian Association of Paediatrics BMI chart for girls from 5 to 18 years by Khadilkar and Khadilkar.[18]

using Chi-square test. For quantitative variable, one-way analysis of variance (ANOVA), i.e., F-test is used. To assess the status of obesity, age-specific BMI percentiles are calculated using IAP growth charts.[14] The underlying normality assumption was tested before subjecting the parameters to ANOVA test. The correlation analysis is done using Pearson's methods. The entire data were entered and cleaned into MS Excel before its statistical analysis. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly.

**Table 2:** The distribution of cases studied according to BMI category based on percentiles (*n*=100).

| BBMI (based on percentiles) | Number of cases (%) |
|---|---|
| UUnderweight (<3rd percentile) | 1 (1.0) |
| HHealthy (3rd–74th percentile) | 75 (75.0) |
| Overweight (75th–89th percentile) | 14 (14.0) |
| Obese (>90th percentile) | 10 (10.0) |
| Total | 100 (100.0) |

Values are *n* (% of cases).[18] BMI: Body mass index

$P < 0.05$ is considered to be statistically significant. All the hypotheses were formulated using two-tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data are statistically analyzed using the Statistical Package for the Social Sciences (Ver. 11.5, Inc. Chicago, USA) for MS Windows.

## RESULTS

The mean age of the menarche of Indian population is 12.5 ± 1.01, underweight girls is 13.7, healthy girls is 12.7 ± 0.93, overweight girls is 11.8 ± 0.99, and obese girls is 11.7 ± 0.89 (Table 1).

The mean BMI is 19.1 kg/m$^2$, SD = 3.2 kg/m$^2$ (range 13.1–29.6 kg/m$^2$). The distribution of cases studied according to BMI category based on percentiles ($n$ = 100) is underweight (<3rd percentile) consisting of one subject, healthy (3rd–74th percentile) consisting of 75 subjects, overweight (75th–89th percentile) consisting of 14 subjects, and obese (>90th percentile) consisting of 10 subjects at the age of menarche (Table 2).

The underweight group displayed a mean menarcheal age of

**Table 3:** The distribution of CVMI staging according to age at menarche (*n*=100).

| CVMI staging | Age at menarche (years) | | | | | *P*-value |
|---|---|---|---|---|---|---|
| | <11.0 | 11.0–11.9 | 12.0–12.9 | 13.0–13.9 | 14.0–14.9 | |
| Stage I | 0 | 0 | 0 | 0 | 0 | 0.064NS |
| Stage II | 1 (20.0) | 9 (32.1) | 8 (24.2) | 17 (63.0) | 0 | |
| Stage III | 4 (80.0) | 10 (35.7) | 11 (33.3) | 7 (25.9) | 3 (42.9) | |
| Stage IV | 0 | 7 (25.0) | 10 (30.3) | 3 (11.1) | 4 (57.1) | |
| Stage V | 0 | 2 (7.1) | 4 (12.1) | 0 | 0 | |
| Stage VI | 0 | 0 | 0 | 0 | 0 | |
| Total | 5 (100.0) | 28 (100.0) | 33 (100.0) | 27 (100.0) | 7 (100.0) | |

Values are *n* (% of cases). *P* value by Chi-square test. *P*<0.05 is considered to be statistically significant. NS: Statistically non-significant. The distribution of CVMI staging did not differ significantly across various age groups of menarche studied (*P*>0.05). CVMI: Cervical vertebrae maturation index

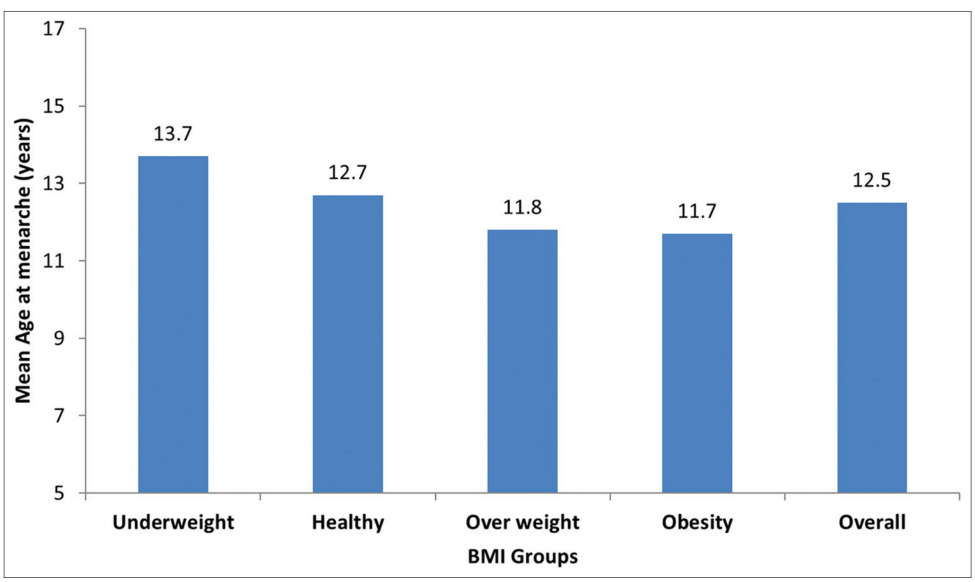


**Figure 2:** The distribution of mean body mass index according to age at menarche ($n$ = 100).

13.7 years, healthy group - 12.7 years, overweight group - 11.8 years, and obese group - 11.7 years with the mean being 12.5 years (Figure 2). The distribution of BMI grading showed an early age of attaining menarche (11.8 and 11.7 years) for overweight and obese girls, but the difference was statistically significant across various age groups of menarche studied (*P* > 0.05).

The distribution of cases studied according to cervical vertebrae maturation index (CVMI) staging (*n* = 100) is 0 cases in Stage I, 18 cases in Stage II, 45 cases in Stage III, 28 cases in Stage IV, 9 cases in Stage V, and 0 case in Stage VI at the age of menarche (Table 3). The distribution of CVMI staging did not differ significantly across various age groups of menarche studied (*P* > 0.05) (Figure 3).

Within the various BMI groups, none represented Stage I, the underweight group was in Stage IV, while the healthy group had 17.33% in Stage II, 42.66% in Stage III, and 33.3% in Stage IV. The overweight group showed 28.7% in Stage II, 42.85% in Stage III, and 14.28% in Stage IV while 70% of the obese group fell under Stage III (Table 4). The distribution of CVMI staging differed

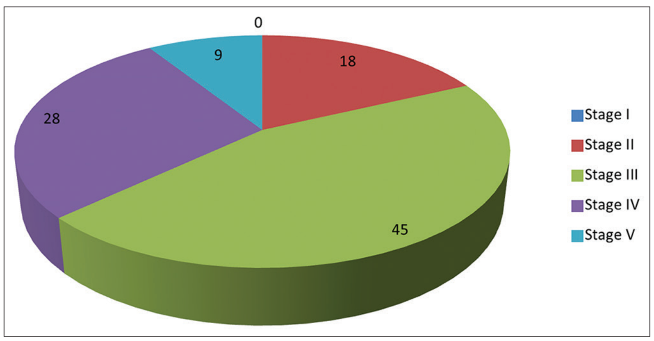


**Figure 3:** The distribution of cases studied according to cervical vertebrae maturation index staging (*n* = 100).

significantly across various BMI groups, i.e., obese and overweight groups lied in the skeletally immature group (C2 and C3) as compared to their healthier counterparts (C3 and C4).

## DISCUSSION

Maturational status can have considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment. Although a number of indicators could theoretically be used, the ossification of the bones of the hand and the wrist was for many years the standard for skeletal development. A similar assessment of skeletal age based on the cervical vertebrae as seen in a cephalometric radiograph has been developed. Since cephalometric radiographs are obtained routinely for orthodontic patients, this method has the advantage that a separate radiograph is not needed, and the assessment of skeletal age from vertebral development seems to be as accurate as with hand-wrist radiographs.[19]

Variation in timing arises because the same event happens for different individuals at different times or, viewed differently, the biologic clocks of different individuals are set differently. Some children grow rapidly and mature early, completing their growth quickly and thereby appearing on the high side of developmental charts until their growth ceases and their contemporaries begin to catch up. All children undergo a spurt of growth at adolescence, which can be seen more clearly by plotting change in height or weight, but the growth spurt occurs at different times in different individuals.[19]

It is often assumed that when a girl attains menarche, she is at the end of her pubertal growth spurt with little or negligible growth left to exploit.[20] The secular trend today suggests that the

**Table 4:** The distribution of CVMI staging according to BMI groups (*n*=100).

| CVMI staging | BMI groups (Indian pediatrics, 2015) | | | | *P*-value |
|---|---|---|---|---|---|
| | Underweight | Healthy | Overweight | Obese | |
| Stage I | 0 | 0 | 0 | 0 | 0.050* |
| Stage II | 0 | 13 (17.3) | 4 (28.6) | 1 (10.0) | |
| Stage III | 0 | 32 (42.7) | 6 (42.9) | 7 (70.0) | |
| Stage IV | 0 | 25 (33.3) | 2 (14.3) | 1 (10.0) | |
| Stage V | 1 (100.0) | 5 (6.7) | 2 (14.3) | 1 (10.0) | |
| Stage VI | 0 | 0 | 0 | 0 | |
| Total | 1 (100.0) | 75 (100.0) | 14 (100.0) | 10 (100.0) | |

Values are *n* (% of cases). *P* value by Chi-square test. *P*<0.05 is considered to be statistically significant. **P*<0.05. The distribution of CVMI staging differs significantly across various BMI groups (*P*<0.05). CVMI: Cervical vertebrae maturation index, BMI: Body mass index

**Table 5:** The distribution of mean BMI according to age at menarche (*n*=100).

| Age at menarche (years) | Underweight (*n*=1) | Healthy (*n*=75) | Overweight (*n*=14) | Obese (*n*=10) | Overall (*n*=100) | F-value | *P*-value |
|---|---|---|---|---|---|---|---|
| Mean±SD | 13.7 | 12.7±0.93 | 11.8±0.99 | 11.7±0.89 | 12.5±1.01 | 6.519 | 0.001*** |

Values are mean±SD. *P* value by F-test - one-way analysis of variance. *P* value<0.05 is considered to be statistically significant. ****P*<0.001. The distribution of mean age a menarche differs significantly across various BMI groups (*P*<0.001). Overall for the entire group of cases studied, the mean±SD of age at menarche was 12.5±1.01 years. SD: Standard deviation, BMI: Body mass index age of attaining menarche has reduced significantly, especially in developing countries. Then, the question of whether skeletal maturation too is attained as early as sexual maturation arises. To address this, the present cross-sectional study aimed at exploring the relationship between age at menarche, skeletal maturation, and BMI percentile in young adolescent Indian female orthodontic patients.

Although the self-reported menarcheal age may cause bias, it has been documented that the recall method is reliable and valid enough for epidemiologic research.[21] Previous studies on the recall age at menarche reported high correlation coefficients between actual age and recall age at menarche with mean errors being lower than 0.5 years. In this study, all the menarcheal ages self-reported by the patients were also verified by the mothers to reduce errors in menarcheal information.

The sample was classified according to BMI percentile-based revised IAP growth charts for height, weight, and BMI for 5–18-year-old Indian children by Indian Academy of Pediatrics Growth Charts Committee *et al*. as underweight (<3rd percentile), healthy (3rd–74th percentile), overweight (75th–89th percentile), and obese (>90th percentile) (Table 2).[22] One girl was found underweight, 75 girls were healthy, 14 girls were overweight, and 10 girls were obese (Table 2). In our study, the sample consists of more healthy subjects than underweight, overweight, and obese subjects which represent the bell curve of any cross-sectional epidemiological study. The mean BMI in our study is 19.1 kg/m$^2$, SD = 3.2 kg/m$^2$ (range 13.1–29.6 kg/m$^2$).

The mean menarcheal age for our sample was 12.5 ± 1.0 years, the mean for underweight girls was 13.7 years, for healthy girls was 12.7 ± 0.93 years, for overweight girls was 11.8 ± 0.99 years, and for obese girls was 11.7 ± 0.89 years which denotes early menarche in obese and overweight girls (Table 5 and Figure 2). The BMI and age at menarche showed inverse relationship. In other words, the overweight and obese girls having higher BMI percentile were associated significantly with early age at menarche and vice versa.

The relationship between age at menarche and socioeconomic status investigated in India by Bai and Vijayalakshmi[23,24] revealed that the mean menarcheal age steadily decreased with the increase in per capita income. It is now generally accepted that protein-rich diet induces an earlier onset of menarche.[25] However, in another study by Padmavathi *et al*. on Andhra state, girls showed attainment of menarche significantly later by non-vegetarian girls as compared to vegetarians.[26] The decline in age at menarche and the increasing number of overweight and obese women, phenomena that are observed in many countries, can have a common hormone-related etiology. Insulin immunity and its metabolism are one of the factors that can influence both the process of biological growth and the BMI throughout the life.[27]

William D. Lassek and Steven J.C. Gaulin (2007) studied the cross-sectional data from the Third National Health and Nutrition Examination Survey (NHANES III) for females aged 10–14 years showed that menarche is more closely related to fat distribution than to skeletal maturity. Similar results were seen in our studies, where we found that the menarche was related to BMI percentile and not to the skeletal maturation.[28]

In our study, we tried to correlate BMI percentile with CVMI staging. CVMI staging differs significantly across various BMI groups. This denotes that CVMI and BMI are interrelated and CVMI can be affected by BMI. According to Hassel and Farman,[7] CVMI denotes overall percentage of skeletal growth expected in an individual which, therefore, can get affected by general health, i.e., BMI percentile. In obese category, maximum girls were found to be in Stage 3, whereas in underweight category, majority of girls were found in Stage 5 in CVMI staging (Table 4). Therefore, obese girls though matured sexually early had more skeletal growth left at the onset of menarche as compared to underweight girls.

The results showed that the distribution of cases studied according to CVMI staging (n=100) is 0 case in Stage I, 18 cases in Stage II, 45 cases in Stage III, 28 cases in Stage IV, 9 cases in Stage V, and no cases in Stage VI, at the age of menarche (Table 4). Therefore, 18 girls were in CVMI 2, i.e. ACCELERATION category and 65–85% of adolescent growth was expected in them, 45 girls were in CVMI 3, i.e., TRANSITION category and 25–65% of adolescent growth was expected, 28 girls were in CVMI 4, i.e., DECELERATION category and 10–25% of adolescent growth was expected, and 9 girls were in CVMI 5, i.e., MATURATION category and 5–10% of adolescent growth was expected.

In our study, we found that the distribution of CVMI staging did not differ significantly across various age groups of menarche studied. This scattered pattern of age at menarche in female patients and CVMI staging shows that none of the stage is particularly related to age at menarche. Therefore, our study states that it is not always necessary that minimal skeletal growth is remaining after the onset of menarche. We found 18 females in CVMI 2 and 45 females in CVMI 3 where 65–85% and 25–65% of adolescent growth expected, respectively.

Another study done by Vichare *et al*. evaluated the interrelationship of various maturity indicators during adolescence in Maharashtrian girls and found that CVMI (CS staging in our study) and SMI were directly related to the chronological age, as well as height and weight at all stages.[29] BMI was directly related to SMI at all stages, but with CVMI, it was not significant at some intervals. A significant correlation was found with SMI and age at menarche, but with CVMI, it was significantly related only at some time intervals.

Eddie Hsiang-Hua (2008)[8] 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 CVMI III, and on average, menarche occurred between CVM Stages III and IV, where skeletal maturation was assessed by six cervical vertebral maturation stages (CVMS) according to Baccetti's latest definition.[2]

Thorough knowledge of patient's skeletal maturity status is important before planning orthodontic treatment. CVMI and CS staging are two most commonly used methods to predict available general skeletal growth and mandibular growth, respectively, before planning the growth modification treatment. The other biological indicators like onset of menarche are often used in orthodontics to predict skeletal maturity. Very less amount of overall skeletal growth and especially mandibular growth is considered to be left after the onset of menarche. However, the results of our study showed no correlation between the menarche and the skeletal maturity. This suggests that the skeletal maturity and sexual maturity are two independently happening phenomena. The orthodontist should be cautious while evaluation skeletal maturity on the basis of sexual maturity, i.e., the onset of menarche.

In summary, the current study demonstrated the relationship between the age at menarche, BMI percentile, and skeletal maturation stages and evaluated the effects of menarche and BMI percentile on skeletal maturation. Our results showed that the female patients were not necessarily at the higher stages of skeletal maturation at the time of attaining menarche. Menarche is usually affected by BMI percentile that is reflection of general health which is supported by our study. We did not find correlation between menarche and skeletal growth. Thus, it can be said that if a female adolescent patient coming for orthodontic treatment and giving a recent history menarche should be carefully assessed for the amount of skeletal growth left, as the results of our study showed variable amount of overall skeletal growth and mandibular growth left at the time of menarche.

A study with a larger sample size on adolescent Indian population would be helpful to further evaluate the menarcheal trend and its relation to skeletal maturation, socioeconomic status, and environmental factors.

## CONCLUSION

The study provided the following inferences:

1. The mean age of menarche of Indian adolescent female population was 12.5 ± 1.01 years. The mean BMI for adolescent female was 19.1 kg/m$^2$, SD = 3.2 kg/m$^2$.
2. The overweight and obese girls got menarche early as compared to healthy and underweight girls. Statistics showed an inverse relation between BMI percentile and menarche.
3. The correlation between CVMI method (Hassel and Farman) and the onset of menarche was statistically insignificant. The orthodontist should be cautious while evaluating skeletal maturity on the basis of sexual maturity indicators like onset of menarche.
4. Significant statistical correlation was found between BMI percentile and CVMI staging method; thus, the girls of the same age were at different CVMI stages depending on their BMI index. Obese girls who have reached the sexual maturity early were skeletally less mature with respect to the overall skeletal growth.
5. The onset of menarche and skeletal maturity are two independent processes and should be correlated with caution before planning orthodontic treatment.

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**Conflicts of interest**

There are no conflicts of interest.

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