DIET AND BODY COMPOSITION AS DETERMINANTS OF MENARCHE

Submitted by

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ABSTRACT

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Two hundred and seven school-going girls who had attained menarche (< 3 months) were studied to examine whether body composition and dietary intake influenced the age of menarche. These girls were selected from three schools in the eastern suburbs of Mumbai and one school from the city of Pune.The anthropometric indices and body composition of the girls were measured, the girls who were taller ($p<0.05$), with a greater percentage of body fat, fat mass and total body water (%) had attained menarche at a younger age when compared to girls who had similar body composition parameters and anthropometric indices at a later age . Significant associations were found between their height (cm), body fat %, fat mass and total body water ($p<0.05$) when observed according to age of menarche. Intake of nutrients such as carbohydrates,, proteins, fats and total energy did not a significant correlation with age of menarche in the present study population. Discriminant analysis highlighted the fact that girls who had an early menarche had body composition and anthropometric profiles similar to girls who attained menarche at a later age in the present sample. In conclusion, age of menarche was influenced by height, body fat percentage, fat mass and total body water percentage.

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INTRODUCTION

Menarche is the culmination of a series of physiological and anatomic processes of puberty and is an important event in girl's reproductive life, because unlike other gradual pubertal changes, menarche dramatically signals the transition from girl to woman. It is marked by the first appearance of the menstrual period in girls and is accompanied with numerous changes in the hormonal secretions and body composition. This transition into adolescence is considered to be a significant developmental period as this life stage brings with it numerous biological, cognitive, and social changes (Conger, 1984). As the onset of puberty and menarche has been viewed as a marker for entry into adolescence, it has received a great deal of attention in research. Particular focus has been upon pubertal timing, or the level of physical and psychological development of adolescents in comparison to same-age peers (Brooks-Gunn & Warren, 1985). In general, timing of menstruation has been the subject of most research in this area.

Early or late onset of menarche has numerous health implications. Early onset of menarche is associated with hormonal imbalances, polycystic ovarian syndrome, childhood obesity and teenage pregnancy. In later stages of life it can give rise to multiple problems like complications during pregnancy, infertility, breast or ovarian cancers etc (Karapanou and Papadimitriou, 2010). Many studies indicate that menarcheal age has also been found to adversely affect cardiovascular disease risk factor changes. Girls with early menarche exhibit elevated blood pressure and metabolic syndrome compared with later maturing girls, independent of body composition (Frontini et al 2003).There is lot of research on age at menarche and it has been estimated that during most of the 20th century age at menarche has fallen by about 3 months per decade (Olga, 2010).

Age at menarche may be determined in part by factors as nutrition, body composition, genetics, altitude of residence, sleep patterns, family size and health status (Warren, 1983;

Golub, 1992; Murata and Araki, 1993) Various studies show, anthropometry, body composition and diet to be correlated strongly with the age of onset of menarche. (Koprowski, (1999); Chumlea (2003) and Lassek and Gaulin,(2006)

Anthropometry has been shown to have an impact on age of menarche. Studies done over the past 100 years show that age at menarche has declined and the adolescent growth spurt has occurred at younger age and peak height growth velocity has increased as well (Prokopec, 1989; Wieringen,1986) The tallest girls (height > 148.6 cm) at the time of first assessment reached menarche at an earlier age than the shortest girls (height < 135.9 cm).(Koprowski, 1999).

Body composition is yet another direct contributing factor for onset of menarche. Body composition collectively describes the different body compartments which constitute the human body; lean body mass, fat mass and water. Acquiring an optimum amount of body fat is essential for the sexual maturation of the individual which is an important factor for onset of menses (Frisch and Revelle 1970). Body composition during puberty is thereby a marker of metabolic changes that occur during this period of growth and maturation, and, thus, holds key information regarding current and future health. Changes in body composition are reflected by changes in BMI, another important factor influencing the onset of menarche. Evidence from several different epidemiologic studies in thepast years indicates a relationship between earlier pubertyin girls and increased BMI, which is the most commonindirect measure of obesity and body fat stores. Studies show that girls who reach menarche at a younger age have higher BMI. (Kaplowitzs, 2001; Koprowski, 1999) and increased body fatness and obesity (Karen, 2002).

Diet on other hand acts as an important key factor regulating body composition and BMI of an individual, therefore diet is thought to have an effect on the age of menarche and thereby

the menstrual pattern. Effect of diet on onset of menarche has been studied extensively, under nutrition and low body fat, or an altered ratio of lean mass to body fat; seem to delay the adolescent spurt and to retard the onset of menarche whereas obesity and high body fat percentage is positively correlated to early attainment of puberty. (Begum, 2000) The quality of food intake also influences puberty for example fat, vegetable and animal protein intakes have shown to greatly influence age of onset of menarche.

All the factors influencing age at menarche are interrelated and hence the onset of menarche cannot be attributed to a single factor. Menarche in general appears to be a complex phenomenon having strong interrelated effect of diet and body composition. A number of western studies have been conducted in the past and present times to understand the complexity of this phenomenon; however studies in India have been limited.

Indian studies have indicated the relationship of early and late menarche with adult body dimensions. Girls with early menarche (age 10 to 11) have been reported to have significantly smaller skeletal dimensions (both longitudinal and transverse) and more subcutaneous fat than those with average or late menarche. The girls with late menarche have on average more height for weight than early maturers and that there is an observed association between menarcheal age and fatness and adult body size (K. Sharma: et al 1988).

Over the past three decades, ideal age for menarche was considered to be 12-14 years; however the studies have reported a steady decline in the age of menarche to be as low as 9 years of age. (Bagga.A, Kulkarni. S. (2000)

Because intake can influence weight through the accumulation of fat and lean tissue, diet may influence age of menarche either directly (diet related hormonal changes) or indirectly (body composition). Thus delayed menarche may be a sign of malnutrition; as nutritional status

improves, the age at menarche is lowered (Acharya, et al 1999). Undernutrition and low body fat, or an altered ratio of lean mass to body fat, seem to delay the adolescent spurt and to retard the onset of menarche whereas obesity and high body fat percentage is positively correlated to early attainment of puberty (Begum et al, 2000).

The mean age at menarche in India was last estimated long ago, and a number of biological, social and ecological factors have likely changed since then. Considering the numerous negative consequences of early menarche, it is opportune to re-assess the age of onset of menarche and its association with various factors, particularly diet composition and body composition. The present study was therefore undertaken with the following objectives:

1) To find out the average age at menarche in school-going girls aged 10 to 14 years.

2) To study the relationship between body composition and age at menarche.

3) To study the effect of dietary intake on the age at menarche

REVIEW OF LITERATURE

Puberty is a dynamic period of development markedby rapid changes in body size, shape, and composition,all of which are sexually dimorphic. It is characterizedby the greatest sexual differentiation sincefetal life. The onset of menarche is a vital maturational event of puberty in female adolescents marking an important milestone in a women's life. Puberty is defined as the period of onset of sexual maturity in which the reproductive organs become functional, and is the time when a child becomes an adult capable of reproduction. In girls, puberty is manifested between 8 and 14 years of age, by growth of the breasts and initiation of menstruation and by the development of pubic and axillary hair. (Krik J., Bandhakavi M., 2008).The physical changes that occur in the female body during puberty probably are more dramatic than those associated with a boy progressing into manhood.

During puberty, the transition is made from having the physical appearance of a child to appearing as an adult (Petersen & Taylor, 1980; Tanner, 1962). In boys, puberty usually begins with the testicles and penis getting bigger. Then hair grows in the pubic area and armpits. Muscles grow, the voice deepens, and acne and facial hair develop as puberty continues, whereas the first sign of puberty in girls is the breast bud formation, the onset of breast development followed by the appearance between the ages of 8.5 to 13 years in 95% of girls and the breasts reach the mature stage between 11.8 and 18.9 years and then finally menarche(Marshall W.A., Tanner J.M. 1969) The adolescent growth spurt, the development of the breasts, and the growth of the pubic hair occur more or less concurrently, and take, on the average, about 3 years from beginning to completion, with menarche occurring usually in the latter half of this period (Tanner, 1962).The Tanner scale also known as the Tanner stages is a scale of physical development in children, adolescents and adults. This scale defines physical measurements of development based on external primary and secondary sex

characteristics, such as the size of the breasts, genitalia, and development of pubic hair, and was first identified by James Tanner, a British pediatrician and thus bears his name. (Marshall, 1969). This scale is commonly used as a marker of female puberty at telarche and menarche.

Table 1: **Tanner Stages Of Female Pubertal Development:**

Age (Years)	**Stages of breast development**	**Stages of pubic hair development in females.**
10 and younger	***B-1***: pre-pubertal	***Ph-1***: pre-pubertal
10-11.5	***B-2***: breast bud	***Ph-2***: sparse growth of long slightly pigmented hair usually slightly curly mainly along the labia
11.5-13	***B-3***: enlargement of beast and areola with no separation of the contours	***Ph-3***: the hair is darker, coarser and curlier and spreads over the junction of the pubes
13-15	***B-4***: projection of areola and papilla to form a secondary mound above the level of the breast	***Ph-4***: the hair spreads covering the mons pubis
15 +	***B-5***: recession of the areola to the general contour of the breast with projection of the papilla only.	***Ph-5*** the hair extends to the medial surface of the thighs and is distributed as an inverse triangle.

Puberty is mainly controlled by neuro-endocrine mechanisms. The onset of puberty is based on many factors but one portion of the body that is crucial is the hypothalamic-pituitary-gonadal (HPG) axis. In girls the last attainment of puberty is menarche.The menstrual cycle is therefore a repetitive phenomenon caused by the interaction of the hypothalamic-pituitary-ovarian system and can be divided into three stages: the follicular phase- recruitment and growth of a new follicle; the ovulatory period- at which time an oocyte is released into the peritoneal cavity; the luteal phase- at which time a newly formed corpus luteum produces progesterone. The cycle is mainly regulated by the hypothalamus, in which gonadotropin-releasing hormone (Gn-RH) is released in pulses to stimulate pituitary gonadotropes to secrete follicle-stimulating hormone (FSH) and luteinizing hormone (LH). These gonadotropins in turn promote follicular development with ovulation and corpus luteum formation in the ovary, inducing steroid hormone production. (Tomoko Fujiwara, Natsuyo Sato, Hiroyo Awaji, 2007) Menstrual health thereby holds a key to the well being of present and future life of a female.Menstrual health is one of the major areas of concern in reproductive health, affecting a large number of women throughout their reproductive life beginning from adolescence. Moreover, menstrual disorders and improper hygienic care have direct consequences in fertility and reproductive tract infections, respectively. (Ray, 2008)

Age at menarche and Secular Trend:

Tanner (1962) described the secular trend in age at menarche.According to Tanner, the average age of menarche dropped from about17 to 12.8 during the period 1830-1962. The rate of decline was 4months per decade. Tanner has also noticed a decline in the age ofinitiation of the growth spurt. The trend seems to have stopped, withthe age of menarche leveling off at 12.6 years.

Sanchez-Andres (1997) studied genetic and environmental factors affecting menarcheal age of daughters and mothers. The mean age at menarche of mothers was significantly greater than in 12 daughters. Year of birth and family size accounted of the variation in age at menarche. They concluded that genetic and environmental factors affects age at menarche, even though the influence of environmental variables may change over time. Graham et al. (1999) studied the secular trend in age atmenarche in rural parts of China. The study showed that the meanage at menarche decreased by 2.8 years from 16.5 to 13.7 over anapproximate 90 years time interval. They found association betweenage at menarche and a number of covariates like country, physicallabour, general health status, exposure to pesticides before menarche.Various studies carried out to record the age of menarche, records from several northern European countries, particularlyNorway, Denmark, and Finland, document that the age of menarche,a convenient marker for the timing of puberty in girls, has decreasedfrom 16 to 17 years during the 19th century to 13 years by themiddle of the 20th century, (Wyshak, 1982) The average menarcheal age in WesternEurope varied between 12.0 yr in Italy (Borneman,1995) and 13.5 yr in the eastern part of Germany (Engelhardt,1995).

In the United States, a declinefrom 14.75 years in 1877 to just under 13 years by the periodof 1950 to 1970 has been reported. (Wyshak, 1982) Findings by Chumlea et al(2003) indicate that 10% of US girls start to menstruate before 11 years, and 90% are menstruating by 13.75 years of age. This distribution of ages indicated that 80% of all US girls start to menstruate between 11.00 and 13.75 years of age with a mean age of 12.43 years. In Thailand and South-American countries such as Chile and Venezuela, the average menarcheal age was reported to be12.5 yr.(Chompootaweep,1997; Ruiz,2000, Macias-Tomei,2000)

*Table 2:*Age at menarche in various countries around the world

COUNTRY	YEAR	AGE
Switzerland	1983	13.4
Belgium	1985	13.1
South Africa	1990	13.2
Japan	1992	12.6
Finland	1993	13.0
UK	1993	13.0
Italy	1995	12.0
Sweden	1996	13.2
Germany	1996	13.5
Hong Kong	1997	12.4
Thailand	1997	12.5
India	1998	12.1
Denmark	1998	13.0
Cameroon	1999	13.2
Greece	1999	12.3
Venezuela	2000	12.6
Netherlands	2000	13.2

USA	2001	12.5
Spain	2002	12.6
France	2006	12.6

Source: Parent A.S. et al, (2003)

It has been widely assumedthat improved health and nutrition associated with the comingof the Industrial Revolution were responsible for most if notall of that decline in the mean age of menarche (Paul, 2008). The declining age of puberty has also been attributed to improved standards of living such as adequate nutrition and health care. (Tomoko Fujiwara, Natsuyo Sato, Hiroyo Awaji, 2007).

Indian data suggests that in the past the age for onset of menarche was 12-14years.However, now there has been a steady decline in the age of onset of menarche to up to 9-10years, thereby making it a topic of interest amongst the researchers. Indian studies have reported that there is a consistent lowering of the menarcheal age (Rakshit 1962; ICMR 1972; Kundalkar 1981;Bagga, 2000) The study conducted by Rakshit. S (1962) reported mean menarcheal age as 14 years and 4 months among Maharashtrian Brahmin women of Nagpur. Similarly the Indian Council of Medical Research (ICMR 1972) reported the mean menarcheal age for Maharashtrian girls as 13 years and 9 months. Kundalkar (1981) reported it to be 13 years and 2 months, and a decade later Bagga(2000) demonstrated the same trend of lowering of age at menarche at 12 years and 6 months. Studies have reported that during most of the 20^{th} century, age at menarche has been falling by about 3 months per decade. (Olga, 2010).Thus, historical data suggests that the timing of pubertyhas been consistently decreasing and that it is influenced by genetic as well as epigenetic factors.

Significance of Age of Onset of Menstruation:

Early or late onset of menarche has many health implications like metabolic syndrome, CVD, Cancers, PCOS as well as infertility making the age of onset of menarche a very important factor for future health of a girl. Early puberty has been associated with increased insulin resistance, total number of metabolic syndrome components and hence increased risk of cardiovascular diseases. (Feng, 2007; Apter, 1989; Remsberg 2002). Age at menarche thereby reflects numerous health aspects of a population including the timing of sexual maturation, growth nutritional status, and environmental conditions. (Wartman ,1970).Numerous studies have been conducted to identify the possible consequences of an early age at menarche (Karapanou O., Papadimitriou A. 2010, Posner B.R. 2006, Frontini M.G. et al 2003, Magnusson C.M. et al 1999, Wyatt G. et al 1999). Other cancers like the cervical (Fujita M. et al 2008), ovarian and the endometrial (Henderson et al., 1981) are associated with early menarcheal age.

Cooper et al (1998) have shown the association between early menarche and the increased risk of ischemic heart disease. The sample comprising 44,899 subjects with years of follow-up and 45 cases of myocardial infarction, angioplasty heart bypass surgery, or ischemic heart disease-related mortality were observed. Early menarche has also been associated with overweight (Wattigney W.A.et al 1999)and metabolic syndrome (Frontini M. G. et al, 2003). Associations of early menarche are seen with higher adult body mass index (BMI), and obesity (Harris M.N.et al, 2008). This study observed that a one year increase in age at menarche was associated with a decrease in mean BMI of approximately 0.5 kg/m. Also the trend toward earlier menarche could be an indicator of a change in insulin-related metabolism.

Indirectly, it also poses a public health concern as it may result in earlier onset of sexual activity (Wyatt G et al 1999). Depression, eating disorders and poor school performance are

among the other teenage problems that have been associated with early menarche (Posner BR, 2006).

On the other hand late menarche is associated with Alzheimer's disease (Parent et al 2003) and skeletal problems such as osteoporosis. Since amenorrheic young women may have reduced bone mineral density at forearm, spine and proximal femur (Cann et al., 1984; Drinkwater et al., 1984), their ultimate risk of fractures and osteoporosis may increased. A recent study by Chevalley T. et al (2009) suggest that in girls experiencing menarche later, report a deficit of peak bone mineral density with very mild increment during the whole period of pubertal maturation. This observation indicates that estrogen exposure is not the only one key factor responsible for the influence of menarcheal age on peak bone mineral density and that other genetic determinants could also be involved

Factors Influencing Age at Menarche:

It is generally accepted that the development of sexual maturity is influenced by both the heredity as well as the environmental factors. (Parent A.S. et al, 2003; Wehkalampi K.et al, 2008; Kaprio J. et al, 1995). The factors related to heredity comprise genetic composition and the maternal age at menarche, while environmental factors include nutrition, physical activity, stress and ethnic and racial differences along with geographical conditions.

Other than these factors many minor factors seem to be affecting the age at menarche. Girls from families with a high socioeconomic status experience menarche at an earlier age than girls from families with lower socioeconomic status. Also, parental educational status has been associated with earlier timing of puberty (Wronka I, 2005). The geographical differences might involve altitude, temperature, humidity, and lighting which signals the hypothalamus-pituitary-gonadal axis mediated through melatonin circuit. This might be the

probable cause of menarche being more frequent in winter than in summer, which points to an inhibitory effect of photostimulation. Stress factors like acute/ chronic illness or war conditions suppress the hypothalamic-pituitary-gonadal axis and delay pubertal onset. Studies performed, in U.S.A. have shown that, black girls experienced menarche, on an average, three months earlier than white girls (Karapanou O.& Papadimitriou A., 2010).Body Composition is another factor influenced by both- the heredity as well as environment. Along with the other factors; nutrition, physical activity and the maternal age at menarche influence the girls' age at menarche. Menarche therefore is regulated by factors such as an appropriate body composition and adequate nutritional status and alteration seen in any of these two components can influence the onset of menarche. Various studies show, anthropometry, body composition and diet seem to be correlated strongly with the age of onset of menarche. (Koprowski, 1999; Lassek and Gaulin, 2006; Chumlea2003)

Age at Menarche and Anthropometric Profile:

Height, Weight and BMI:

The onset of puberty corresponds to askeletal (biological) age of approximately 11 years ingirls and 13 years in boys (Tanner, J M; et al 1975). On an average, girls enterand complete each stage of puberty earlier than boys,but there is significant intraindividual variation inthe timing and tempo of puberty, even among childrenof the same gender and ethnic background.One of the hallmarks of puberty is the adolescentgrowth spurt. As puberty approaches, the growthvelocity slows to a nadir ("preadolescent dip") beforeits sudden acceleration during mid-puberty. Thetiming of the pubertal growth spurt occurs earlier ingirls, typically at Tanner breast stage 3, and does notreach the magnitude of that of boys. Girls average apeak height velocity of 9 cm/year at age 12 and atotal gain in height of 25 cm during the pubertal growth period (Marshall WA, Tanner JM, 1975). Boys attain a peak

height velocityof 10.3 cm/year, on average, 2 years later thangirls, during Tanner genital stage 4, and gain 28 cmin height(Marshall WA, Tanner JM, 1970). The longer duration of prepubertalgrowth in combination with a greater peak heightvelocity results in the average adult height differenceof 13 cm between men and women (Tanner, J M, 1989).

***Table 3*: Changes in height of pubertal girls (adapted from Tanner, 1985)**

TANNER STAGES	AGE (years)	INCREASE IN HEIGHT(cm)
I	10 and younger	Height increases at basal rate: 5-6 cm/year
II	10-11.5	Height increases at accelerated rate: 7-8 cm/year
III	11.5-13	Height increases at peak rate: 8 cm/year
IV	13-15	Height increases at 7 cm/year
V	15 +	No further height increase

Tanner (1985) suggests that there is an increase in height throughout puberty and that Peak height velocity occurs at 11.5 years (9.7-13.3 years) whereas the Basal growth occurs until Tanner Stage 2 further he suggests that girls with an increase in height by about 9.0 (7.0-11.0) cm/yr mature early as compared to girls who mature late with an increase in height of 7.5 (5.4-9.6) cm/yr.

Other authors have also reported that postmenarcheal girls were taller than their premenarcheal counterparts of the same age. (Bauer, 2007: Kirchengast, 2007). The tallest girls (height > 148.6 cm) at the time of first assessment reached menarche at an earlier age than the shortest girls (height < 135.9 cm); the RH was 2.9 (95% CI 2.1–4.1) according to Koprowski (1999).Similarly,it was observed that girls with the largest body mass (QI > 20.7) reached menarche sooner than girls with the smallest body mass (QI < 16.1, RH = 2.2, 95% CI 1.7–2.9).

Studies on relationships between body size(height and QI) and menarche have consistently reported that taller girls attain menarche earlier than their shorter counterparts with those (Moisan et al, 1990*a*, 1990*b*; Maclure et al, 1991; Merzenich et al, 1993). It has also been demonstrated that skeletal development, as measured by height, is related to menarche. And that taller girls were more likely to experience menarche at an earlier age also in the past a number of investigators have proposed that age at menarche is closely related to skeletal maturity (Ellison, 1982; Elizondo, 1992;Koprowski,1999) recent study showed similar results that the menarcheal girls were taller than non-menarcheal ones.(Ji-Yeong Kim,2010)

Body weight has also shown an effect on age of menarche. Kirchengast, (2007) reported that postmenarcheal girls exhibited a higher weight status, a higher absolute and relative amount of fat mass and a higher amount of lean body mass than their premenarcheal counterparts of the same age.Studies carried out in the past by Shuttle worth (1937), (1938); Simmons and Greulich (1943); Simmons (1944); Marshall (1974) show that there is a close association between menarcheal age and skeletal maturation.

However, Frisch and Revelle (1970) suggest that menarcheal age is related to attainment of appropriate weight for reproduction rather than appropriate skeletal status. According to

Frisch, a minimum level of fatness (17% of body weight) is associated with menarche; however, a heavier minimum weight for height, representing an increased amount of body fat (22%), appears necessary for the onset and maintenance of regular menstrual cycles. Body weight also has shown an impact on the age of menarche, the girls who achieved menarche earlier (between 9-11 years) showed the maximum mean body weight (46 kg) being 5 kg more than the mean weight of the girls in ideal age group. The late menarche group of girls showed the least mean body weight (37 kg)which was about 4.5 kg less than that of the ideal group(Bagga , 2000) recent study showed similar results that the menarcheal girls were heavier than non-menarcheal ones.(Ji-Yeong Kim,2010)

Body mass index (BMI) is a commonly used index of body composition (adiposity). It is defined as weight in kilograms divided by the square of stature (standing height) in meters. BMI is proportional to weight and inversely proportional to the square of the height. BMI is often used to determine overweight and obesity in the clinical environment, usually by comparison of an individual to age- and sex-specific percentiles from a reference population. (Flegal, 2000)

Bock(1994) analysed BMI in two cohorts, cohort 1 (born 1929–1954) and Cohort 2 (born 1955–1982) wherein girls were followed longitudinally from 6 years before menarche to 6 years after menarche and it was reported that there was a large and significant difference between the two cohorts in BMI suggesting that onset of menarche can be governed with an increase in BMI also evidence from several different epidemiologic studies in thepast 30 years indicates a relationship between earlier pubertyin girls and increased BMI, which is the most commonly availableindirect measure of obesity and body fat stores.

Edward(2007) investigated that the BMI of the girls was related to the age of onset of menarche as the BMI increased the age of menarche decreased and this study was consistent with findings which reported that BMI is a contributing factor in the age of onset of puberty[Palmert,(2001), Fredricks(2005) Kaplowitz, (2001), Janssens, (2003)]. A recent study also reported of higher BMI and greater waist circumference in menarcheal girls as against the non menarcheal ones.(Ji-Yeong Kim,2010). However, a study by John(2008)pointed out that the average effects of menarcheal status on BMI assessments of overweight and obesity are small.

Body weight, height, BMI and body composition of a subject are therefore very important parameters reported in literature to influence the age at menarche (Awadhi et al, 2013; Banerjee et al, 2007; Deo and Gattorgi, 2004 Lin-Su et al, 2002 and Mohammad et al, 2013). A recent longitudinal study provides further evidence for a link between body weight and onset of puberty, as those girls that had a higher body weight or body mass index earlier in childhood were more likely to initiate reproductive development at nine years of age than their peers (Davison et al. 2000).

The findings from the studies of Moisan et al 1990a and 1990b demonstrated that skeletal development, as measured by height is related to menarche. A close relation between skeletal maturity and the age at menarche showing that taller girls are more likely to attain menarche at an earlier age was observed by various investigators (Ellison T, 1882; Elizondo et al 1992; Koprowski et al 1999). A study done in California showed that taller girls (148.60 cm) experience menstruation earlier than shorter ones (135 cm). (Kaplowitz and Kaplowitz, 2011) Similar results were seen in a recent study that the menarcheal girl were taller than the non-menarcheal ones (Kim J.Y. et al 2010).

Waist circumference is a more accurate measure of the distribution of body fat. BMI and waist circumference are primary tools for assessing adiposity. Waist-to-height ratio and BMI-for-age are similar; waist-to-height ratio may be preferred as an indicator of obesity related Risk (Ashwell M., 2005; McCarthy H.D., 2006). The waist-to-height ratio was first used in the Framingham Study (Higgins M,1988), and several studies of children (Savva SC, 2000; Hara M, 2002; Kahn HS,2005) and adults (Hsieh SD,2005; Bosy-Westphal A,2006) have concluded that this ratio is more strongly associated with CVD risk factors than is the body mass index (BMI; in kg/m2).

Age at menarche and Body Composition:

The human body is composed of fat mass as well as fat free mass, thus it is found that anthropometric parameters, such as weight, height and BMI are strongly correlated with age at menarche. To start menstruation, girls need to achieve a minimum weight of 47.8 kg; and more importantly, their body fat should amount to 23.7%.It may also occur when enough gonadotropin hormones are released from the pituitary and hypothalamus. (Frisch, 1974). Studies show that body composition during puberty is a marker of metabolic changes that occur during this period of growth and maturation, and, thus, holds key information regarding current and future health. During puberty, the main components of body composition (total body fat, lean body mass, bone mineral content) all increase.(Siervogel, 2003) Monitoring body composition during puberty is important because many aspects of body composition during this period are predictive of subsequent measures ofthese traits in adulthood (i.e. body composition ‘tracks’, Guo ,2002,2000). Furthermore, certain aspects of body composition and their changes during puberty are risk factors for a variety of common, multi-factorial

adult diseases, including cardiovascular disease, diabetes mellitus, obesity and osteoporosis (Chumlea ,2002, Siervogel,2000).

Considering the effect of body composition on menarche acquiring an optimum amount of body fat and body weight is essential for the sexual maturation of the individual which is an important factor for onset of menses.(Matkovick,1997) There have also been studies to suggestthat obese girls tend to mature earlier than normal and that"thin" girls tend to mature later. For example, a significantdelay in puberty and menarche is seen in girls who are veryphysically active and have markedly diminished body fat (Warren, 1983). Higher subcutaneous fat levels and BMI at prepubertal ages (5-9 yrs) were associated with increased likelihood of early (<11years) menarche. (Bagga and Kulkarni, 2000; Freedman et al, 2002). Study conducted by Ajita and Jiwanjot (2014) states that the body mass index and body fat percentages were significantly correlated and an inverse correlation was found. The higher body mass index, the lower was the age at menarche (Bralic et al, 2012; Currie C et al, 2012; Oh CM et al, 2012 & Wronka, 2010).

WHR is another parameter of body composition of an individual some researchers found an association between body composition and waist to hip ratio. Female waist-hip ratio (WHR) declines during childhood from 1.03 at 4 months of age to 0.78 at the time of menarche (Fredriks et al., 2005), and there is a steep increase in hip circumference just before menarche (Forbes, 1992). Lassek and Gaulin,(2006) suggested that menarche may be related to fat distribution rather than total fat, and in particular to the relative amount of lower-body fat (gluteofemoral) vs. upper-body fat. However Frisch and Revelle (1970)suggested that body composition parameters such as lean body mass and absolute and relative fat mass were significantly associated with menarcheal status.

Another important aspect of body composition during puberty is the adipose tissue which is an active endocrine organ and adipocyte-secreted proteins which are produced in response to

a variety of changes in metabolic status (Holst,2002) .Adipocytokines (adipose tissue-derived molecules) include leptin, adiponectin and resistin. Leptin functions as a regulator of energy balance by interacting with several neuropeptides to inhibit food intake, and affecting the expenditure of energy. Leptin also appears to be involved in mediating various endocrine mechanisms like onset of puberty or insulin secretion and is related to disorders including obesity and polycystic ovary syndrome (Remsberg ,2002). Leptin is primarily synthesized in adipose tissue, but is also synthesized in the stomach, placenta, mammary glands and ovarian follicles, as well as other organs. Leptin is strongly related to TBF, This hormone , produced by fat cells, provides a pathway to communicate the size of fat stores to the GnRH secreting neurons in the hypothalamus via leptin receptors in KiSS-1 neurons (Smith et al., 2006) and is required for puberty (Chehab et al., 1996, 1997; Clement et al., 2007; Ozato et al., 1999; Farooqi et al., 1999), several studies also show that age at menarche in young women is inversely related to leptin levels (Matkovic et al., 1997) if young women with relatively more gluteofemoral fat produce more total and free leptin, this may increase GnRH pulse frequency and the likelihood of menarche,(Lassek, 2006). It is anticipated, therefore, that leptin deficiency is a primary reason for delayed puberty and menarche in individuals and in populations accustomed to absolute or relative dietary energy deficiency. In menstruating women, a negative energy balance caused by either fasting and/or exercise could cause secondary amenorrhea , presumably due to low levels of circulating leptin.(De Souza,1991) Elevation of the serum leptin level, which precedes puberty, is thought to play an important role in the onset of puberty.

All of the studies that show a relationship between early pubertyand obesity in girls do not answer the question of whether increasedbody fat predisposes girls to earlier puberty or earlier pubertyin some girls leads to an estrogen-mediated increase in bodyfat. A review of

the effects of gonadal steroids on body compositionin adults concluded that estrogens and possibly progesteronelargely account for the greater degree of body fatness in womenas opposed to men, because these hormones seem to work togetherto favor the storage of excess calories as fat, with estrogenspromoting deposition of fat in peripheral adipose tissue depots.(Rosenbaum, 1999)

Age at Menarche and Nutritional Status:

Nutritional status and dietary composition have an important bearing on age at menarche i.e. the quantity as well as quality of food intake influences puberty. Adolescents gain 50% of adult weight and more than 20% of their adult height during this period.(Berkey et al, 2000; Bharti, 1998). Studies report that delayed menarche may be a sign of malnutrition and as nutritional status improves, the age at menarche is lowered drastically.(Abioye-Kuteyi , 1997; Acharya.,2006)

Studies suggest that there is a strong correlation between body composition and menarcheal pattern influenced by the dietary pattern of adolescent population.It has also been suggested that decreases in age at menarche until the mid-1960s resulted from "positive" changes, such as better nutrition, whereas decreases since that time are related to "negative" changes, such as overeating and decreased physical activity (Paula .2008). It has been suggested that girls need to reach a critical weight or height for menarche to occur and that changes in dietary habits as observed in children may cause this critical weight to be reached at an earlier age . Up to now it is unclear, however, whether energy intake or specific nutritional components play a role, or whether Nutrition affects menarche through its effect on accumulation of adipose tissue(Onland-Moret, 2005).

Dieting behaviors and nutrition can have an enormous impact on the gynecologic health of adolescents. A strong secular trend has been observed; in all developed countries girls have

shown a preponed menarche. Some authors consider that chronic malnutrition as seen in many developing countries is the main determinant of delayed puberty. (Driezen et al. 1967, Kulin et al. 1982, Eveleth and Tanner 1990). Kulin H.E. et al (1982) compared between 342 privileged, urban children and 347 impoverished rural adolescents in Kenya and found that chronic malnutrition leads to a delay in menarche of girls by 2.1 years. This could be attributed to the effects of chronic malnutrition in the first decade of life leading to stunting as the mean height differences of 7.4 cms was found in both the groups in their pre pubertal stages in spite of catch up growth in early years.Similar studies in the American population have shown a delay of 2 years in menarche (Dreizen S, Spirakis C.N., Stone R.E. 1987) and a delay of 1½ year in Indian girls (Satyanarayan K., Naidu N., 1970).The oldest age of menarche was noted when the protein, iron and caloric intake was less than 80% of the RDAs. (Mounir,2007). Observational studies suggested a role of dietary intakes during prepuberty; high intake of proteins, low intake of fat, high fiber, high isoflavones and calorie restricted diet shows a delay in menarche. Fussy eating habits and under nutrition subsequently leading to poor health have been considered as a reason for late menarche as well (John C, 2008).

On the other hand, a diet high in fats and animal proteins has been associated with early menarche. A study conducted by Prakash. C (2010)reported that the girls having non vegetarian diet had significantly earlier onset of menarche and thereby showed a positive correlation of age of menarche and non vegetarian diet.

Animal protein and vegetable proteins have been shown to have different effects on the age at menarche. Children with higher animal protein intake experience early menarche as compared to those on higher vegetable protein intake (Buyken,2010). Bagga.A and Kulkarni (2000) have also demonstrated that early menarche is associated with a change in food habits from vegetarian to eggetarian and non-vegetarian diets. Similarly some studies suggest that

greater intake of milk or milk-derived nutrients such as calcium, protein, or fat contributed to earlier menarche (Chevalley ,2005;Berky, 2000)whereas another study stated that only greater total calcium and milk intake contributed to a higher risk of early menarche(Andrea S.W,2011). Meyer et al. (1990) found that higher dietary energy intake was associated with earlier menarche and dietary composition was not however many other studies report that not only dietary intake but individual intake of nutrients also play an important role.

A plethora of other dietary factors seem to be influencing the age of onset of menstruation (early or late onset) such as a higher fiber intake (Koo,2002: Thijssen ,1991) or higher intakes of carbohydrate and micronutrients (Kissinger,1997), lower intakes of vitamin C, vitamin E, β-carotene and higher leptin concentrations (Aeberli,2006; Foster ,1999) indicating probable associations between diet quality in the prepubertal period with the timing of puberty onset. Nutrient intake and storage during childhood may influence the timing of menarche through hormones such as leptin and insulin, and growth factors such as Insulin-like Growth Factor I (IGF-I), all of which are involved in the regulation of growth and maturation. (Parent, 2003)
There is therefore substantial evidence that the timing of onset of menarche has numerous health implications, and that adolescent growth and development factorsare somehow causally associated with risks of adult diseases. Therefore their associations with earlier, potentiallymodifiable childhood factors are relevant to disease prevention.

METHODOLOGY

The present retrospective study has been conducted with the objective of determining the age at menarche as influenced by the dietary pattern and body composition. The sample size was decided to be 200 in consultation with the statistician.

Sample Selection:

The subjects for the study were school girls in the age group of 10-14 years (5^{th} - 8^{th} standard) of various schools from two important metro cities in Maharashtra namely Mumbai and Pune. The school principals were first approached with an official letter to seek permission for the study (Appendix A). On obtaining approval from the school authorities, girl students from class 5 through class 9 were given a preparatory talk in different sessions as arranged by the school authorities. In this preparatory talk session the girls were introduced to physiological and anatomical changes taking place during puberty, the onset of menarche and the menstrual cycle. Following this talk, a pre questionnaire (Appendix B) was administered to identify the girls who had recently attained menarche, for inclusion in the sample group as defined by the inclusion and exclusion criteria. A consent letter was sent along with the selected girls to be signed by the parents indicating their agreement to participate in the study (Appendix C). Mothers of these girls were later invited for a meeting (Appendix D) to obtain information regarding their demographic profile, family medical history, menstrual details and pattern of physical activity using a closed ended general questionnaire (Appendix E) along with 24-hour Diet Recall (Appendix F) and Food Frequency Questionnaire (Appendix G). Based on the willingness of girls and their mothers to participate in the study, 200 subjects who had attained menarche with their mothers were enrolled for the study.

TOOLS OF DATA COLLECTION:

General Questionnaire:

The general questionnaire was used to obtain information regarding name, date-of-birth, age of the subjects, parents' occupation, monthly family income, their medical history along with the family medical history.

24 Hour Diet Record:

To gain information on the girls' dietary pattern, a 24hr diet record form was given to them along with directions to fill it. They were instructed to record all the foods consumed in a day (including meals taken at home, at school, etc)with its quantities and ingredients as far as possible. However, the amounts mentioned were based on approximations and were not accurate

Food Frequency Questionnaire:

Food frequency questionnaire (FFQ) was designed in order to validate the 24-hr food record. It contained 100 foods from various food groups such as breakfast items, sweet preparation, milk based recipes, protein supplements, fried snacks, chat items, fast food, and non vegetarian foodstuffs etc. Food frequency questionnaire was filled by an interview method in which parents were given assistance regarding the portion sizes and actual quantities consumed by their daughters. For this, paper cut models of chapatti, puri, phulka, were prepared and standard cups, table spoon sets other serving spoons and plates were carried and shown to them.

Anthropometric Measurements:

The following anthropometric measurements were collected.

- **Weight (kg)** was measured using an electronic weighing scale (Nova BGS-1204). The accuracy of the scale was ± 100g. The subjects were asked to stand, barefoot on the center of the weighing scale without moving, tilting or holding anyone or anything else. Weight was recorded nearest to 100g.

- **Height (cm)** was measured using a portable stadiometer. The subjects were asked to stand barefoot on the stadiometer, with their mandibular plane parallel to the floor and the height was measured to the nearest 0.1cm.

- **Body Mass Index (kg/m^2)** was calculated as weight in kilograms divided by the square of height in meters.

$$BMI\ (kg/m^2) = \frac{Weight\ (kg)}{Height\ (m^2)}$$

- **Waist Circumference (cm)** was also measured with a non-stretch measuring tape. It was placed half way between hip bone and lowest rib of a subject. This was about 5 cm (2 inch) above belly button. The measuring tape was wrapped around the waist and the measurement where the two ends of the tape meet was noted.

- **Hip Circumference (cm)** was also measured with a non-stretchable measuring tape. It is measured at its widest portion of the buttocks. The measuring tape was wrapped around the hip and the measurement where the two ends of the tape meet was noted.

- **Waist to Hip Ratio (WHR):**One of the simplest ways of measuring body fatness is calculating waist-to-hip ratio, a relationship between waist circumference and hip circumference.

$$\text{WHR} = \frac{\text{Waist (cm)}}{\text{Hip (cm)}}$$

- **Body composition analysis** was conducted using a Body composition analyzer (Tanita model no. BC 420 P MA) which works on the principle of Bio electrical impedance. The general principle behind BIA: two conductors are attached to a person's body and a small electric current is sent through the body. The resistance between the conductors will provide a measure of body fat, since the resistance to electricity varies between adipose, muscular and skeletal tissue. Fat-free mass (muscles) is a good conductor as it contains a large amount of water (approximately 73%) and electrolytes, while fat is anhydrous and a poor conductor of electric current. The girls were asked to stand on the machine bare feet wearing their uniforms, the age (years) and height (cms), were entered manually. The values and measurements for the following parameters Weight(kg), BMI(Kg/m2), Skeletal muscle mass (Kg), Fat mass(kg), Fat percentage, Total protein (kg), total body water (kg), WHR were automatically obtained on the analyzer and were printed as a graph.

Statistical Analysis:

The data from the General questionnaire, 24-hr Dietary recall, and BCA was coded on a code sheet using Microsoft Excel-2007 spreadsheet. All entries were double checked for any possible keyboard error. This data was analyzed with the help of statistical package SPSS Version-17.

The techniques used for analysis were:

- Frequency, mean and standard deviation for the general questionnaire
- Correlations using Karl Pearsons' Coefficient of Correlation for determining the relationships between:
    - ✓ Age at Menarche and Body Composition,
    - ✓ Age at Menarche and Dietary-intake.
- Regression and Discriminant analysis to predict the age at menarche from dietary intake and body composition.

RESULTS AND DISCUSSION

Sexual maturation in the female is marked by menarche, the first menstruation. Menarche typically occurs after the peak of theadolescent growth spurt. It follows the appearance of pubic hair,breast development and mature patterns of fat deposition. Menarchemay be stimulated by attainment of critical weight. It may also occurwhen enough gonadotropin hormones are released from the pituitaryand hypothalamus. The menstrual cycle is the result of highlyregulated cyclic fluctuations of the protein hormones from the anteriorpituitary that act on the ovary. These fluctuations are followed bycorresponding fluctuations of steroid hormones from the ovary that acts on the endometrium. Age at menarche is influenced by a numberof factors including genetic factors, anthropometric indices, body composition, diet, physical activity, etc. Inthe present study an endeavour has been made to study the effect of body composition and dietary intakeon the age at menarche.

The study population consisted of 207 girls in the age group of 10 to 14 years i.e 5^{th} to 9^{th} standard. A General questionnaire administered to all the students was used to collect data regardingdemographic details such as occupation of mother/father or both, monthly family income, number of family members. The general questionnaire also included questions regarding the subjects' medical history and the medical history of their family members, age at menarche, menstrual cycle details and pattern of physical activity. Analysis of the information revealed the following:

Parents' Occupation; Of the 207 subjects, fathers of a majority of the subjects i.e. 51% (n=106) were in service while 29% (n=60) were self employed. Fathers' of almost 20% (n=41) of the students were unemployed. (Figures 1 &2)

Fig 1: **Fathers Occupation**

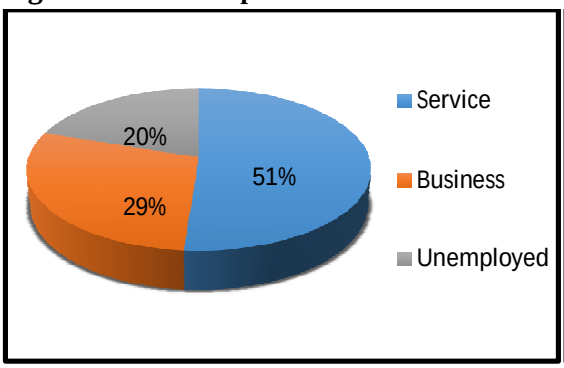
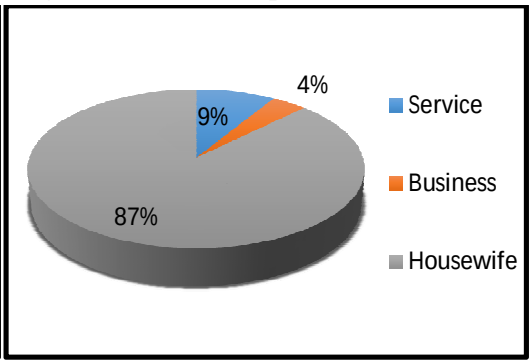


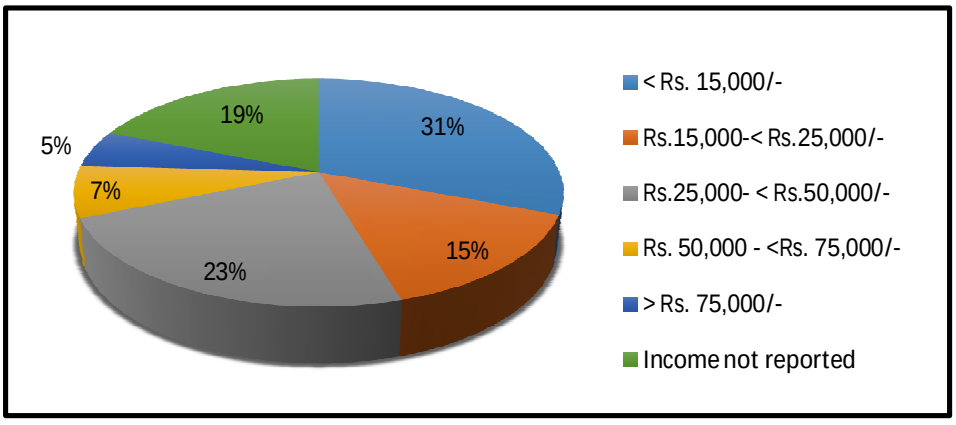
Fig 2: Mothers' Occupation



As far as the mothers were concerned a majority of them were homemakers .i.e. 87% (n=181) and only 13% (n=26) of them were working women.

Monthly Family Income: Information on monthly family income showed that approximately half of the subjects i.e. 45% (n=94) belonged to families earning less than Rs. 25,000/- per month while students belonging to families with a monthly family income between Rs. 25,000/- – Rs. 50,000/- constituted only about 15% (n=41) of the sample.

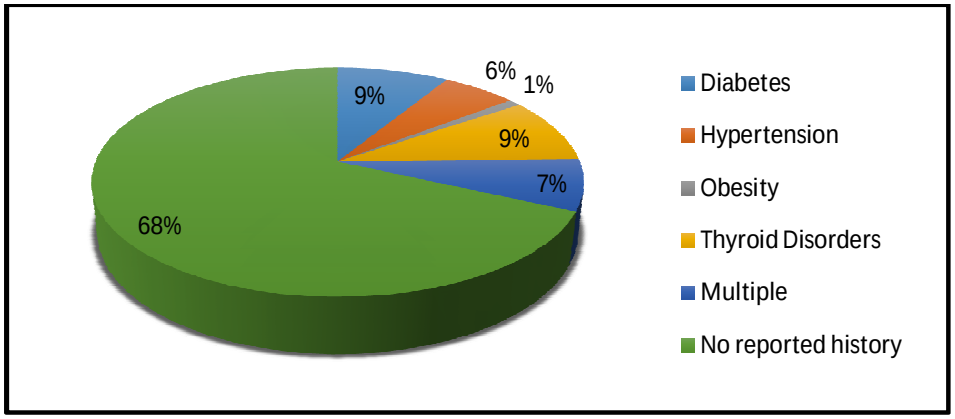
Fig 3: Monthly Family Income



Only 20% (n=26) of the students belonged to high income families i.e. a monthly family income of more than Rs. 50,000/-. Almost 18% (n=39) of the subjects did not respond to this question.

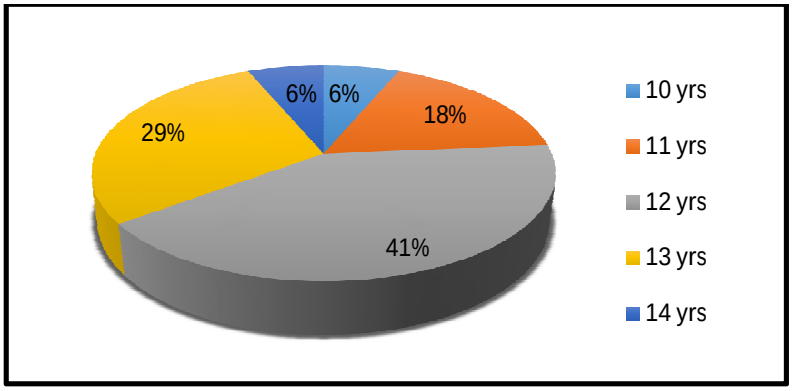
Medical History: As far as medical history of the subjects and their families are concerned, a majority of the subjects i.e. 68% (n=141) reported that there was no family history of disease including themselves. The remaining 25% (n=51) of the subjects reported atleast one health problem like diabetes, hypertension, obesity and thyroid disorder. Only 7% (n=15) subjects said that there were family members suffering from multiple disorders.

Fig 4:Family history of Illness



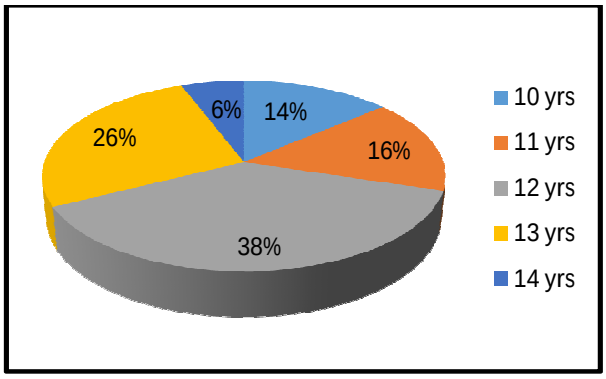
Age of the Sample: The average age of the sample was 12.65±0.906 years. The age distribution within the sample is as shown in the figure 5.

Fig 5:Age distribution of the sample



Age at Menarche: The mean age at menarche of the sample (n=207) was 12.12±0.978 years (Fig. 6)

Fig 6: Average age at Menarche



With regards to the menstrual pattern among the girls: as seen in Fig 7 most of the subjects i.e. 66% (n=136) reported a regular menstrual cycle of 28 – 30 days while 15% (n=32) of the subjects had an irregular cycle. Approximately 19% (n=39) did not provide any information in this regard. The average duration of the menstrual period was 4-6 days for 54% (n=91) of the subjects. Of the remaining subjects 30% (n=51) reported a longer duration of >6 days while 16% (n=26) reported a shorter period of <4 days (Fig. 8)

Fig 7:Regularity of Menstrual cycle

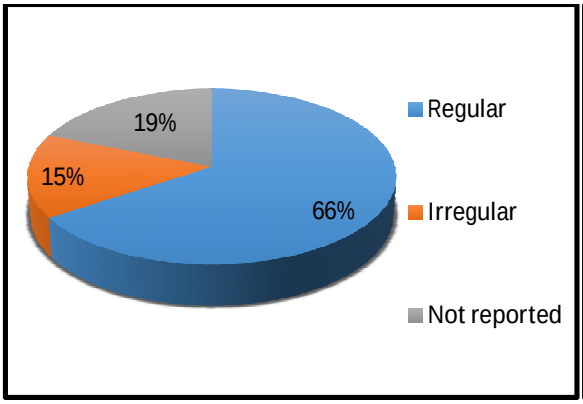
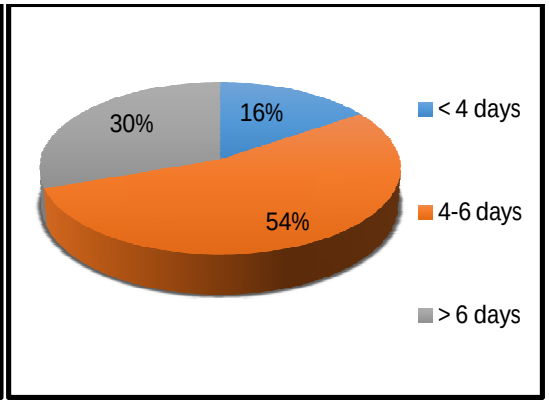


Fig 8:Duration of Menstrual period



Age at Menarche and Anthropometric profile:

Height and weight of the girls were recorded and BMI was calculated for the total population. The results obtained are shown in table 4:

Table 4 : Anthropometric Profile of the study population

Anthropometric Measurements	N	Mean ± SD
Height (cm)	207	150.38±6.086
Weight (Kg)	207	43.709 ± 9.6660
BMI (Kg/m^2)	207	19.251 ± 3.7129
Waist circumference (cm)	161	69.16 ± 8.561
Hip circumference (cm)	161	85.17 ± 8.851
WHR	161	0.8109 ± .05591

When the data was analyzed to study the correlations between the anthropometric profile of the study population with the age at menarche using Karl Pearsons' Coefficient of Correlation, it was seen that the p value for height is <0.05 indicating that an increase in height is positively correlated with age at menarche (p value <0.05 sig.2 tailed)i.e. girls who

attained a taller stature earlier than their counterparts of the same age, reach menarche earlier (Table 5)

Table 5 :Correlation between Age at menarche with anthropometric measurements

Parameters Tested	Pearson Correlation		
	Pearson Correlation	**N**	**Sig. (2-tailed)**
Height(cm)	.166(*)	207	.017
Weight(kg)	.024	207	.726
BMI(kg/m^2)	-.045	207	.521
Waist circumference	-.012	161	.884
Hip Circumference	-.028	161	.729
WHR	.019	161	.813

(*p value < 0.05)

However, there was no significant effect of other anthropometric parameters such as weight, BMI, waist circumference, hip circumference, WHR on the age at menarche in the present study population.

But, as seen in table 6, discriminant analysis of the age at menarche and the various anthropometric indices such as height, weight, waist circumference, hip circumference, waist-

to-hip ratio, do seem to suggest that younger girls who attained menarche had anthropometric measurements comparable to girls who attained menarche when they were older.

Table 6 : Discriminant Analysis of Age at Menarche with Anthropometric Indices

Age at Menarche (years)	N	Height (cm)	Weight (kg)	BMI (kg/m^2)	Waist Circumference (cm)	Hip Circumference (cm)	WHR
10	13	148.08 ± 6.861	46.869 ± 8.893	21.282 ± 3.350	73.60 ± 9.359	88.90 ± 10.322	0.8250 ± 0.0583
11	36	149.39 ± 5.699	42.383 ± 8.697	18.975 ± 3.724	69.88 ± 8.829	84.62 ± 9.500	0.8254 ± 0.0514
12	85	149.65 ± 6.035	42.867 ± 9.576	19.040 ± 3.631	67.66 ± 7.785	84.76 ± 8.755	0.7971 ± .0561
13	60	152.85 ± 5.698	44.948 ± 10.516	19.145 ± 3.796	69.15 ± 8.951	84.92 ± 8.131	0.8117 ± 0.0548

14	13	148.85 ± 5.829	44.008 ± 9.461	19.854 ± 4.046	74.33 ± 8.185	84.11 ± 10.493	0.8544 ± 0.0412
Total	207	150.38 ± 6.086	43.709 ± 9.666	19.251 ± 3.713	69.16 ± 8.561	85.17 ± 8.851	0.8109 ± 0.05591

Though the results obtained from our study are not statistically significant, they are in agreement with a longitudinal study done by Berkey (2000) on Caucasian girls suggesting that, girls who were taller at ages 6-8 years had earlier age at peak growth velocity and earlier age at menarche. Kirchengast and Bauer, (2007) have similarly suggested that, girls who achieved menarche at an early age are significantly taller and heavier than their non menarcheal counterparts even between the ages of 11-14years. A study done in California showed that taller girls (148.60 cm) experience menstruation earlier than shorter ones (135 cm) (Kaplowitz and Kaplowitz, 2011). Similar results were seen in a recent study that the menarcheal girl were taller than the non-menarcheal ones (Kim J.Y. et al 2010).A survey on physical measurements of youth in 2005 also showed that the group that experienced menarche between the ages of 11 and 13 had greater height, weight, and BMI than those of the group that did not experience menarche during those ages (Kim JY, Oh IH, 2010). A study using National Health and Nutritional Examination Survey 2005 also found that the group that experienced menarche had greater BMI than the group that did not, even after adjusting for age (Cho GJ, Park HT, 2010). In Korea, the continuous decline of the age at menarche and increase in BMI among adolescents suggest that the earlier age at menarche may be associated with increase in BMI, which is a surrogate indicator of body fat percentage (%) (Ku SY, Kang JW,2006; Cho GJ, Park HT,2010) .

Age at Menarche and Body Composition:

Monitoring body composition during puberty is important because many aspects of body composition during this period are predictive of subsequent measures of these traits in adulthood (i.e. body composition ‘tracks’) [Guo,2000,2002]. Body weight, BMI and body composition of a subject are also very important parameters reported in literature to influence

the age at menarche (A-Awadhi et al, 2013; Banerjee et al, 2007; Deo and Gattorgi, 2004 Lin-Su et al, 2002 and Mohammad et al, 2013).

***Total Body Fat Percentage*:** Body fat percentage is the amount of body fat as a proportion of your body weight. Percentage Body Fat indicates the percentage of body fat to body weight.

Percentage Body Fat (%) = Body Fat Mass / Body Weight× 100.

Fat Mass - Body Fat Mass (FM) can be stored under the skin, as well as in the abdomen. When a person's body fat mass is higher than the standard range, they are clinically obese.By knowing the percentage of body fat, multiplying Body fat % by weight gives us the exact weight of fat in our body.

Body Fat Mass (kg) = Body Weight (kg) – Fat Free Mass (kg).

Fat Free Mass - Fat Free Mass (FFM) is basically everything that is not fat: muscle, water, bone, connective tissue, etc.

***Muscle Mass*-**Muscle mass indicates the weight of muscle in our body. It includes the skeletal muscles, smooth muscles (such as cardiac and digestive muscles) and the water contained in these muscles.

The body composition profile of the present study population was assessed and the results are as presented in table 7:

Table 7 : Body Composition Profile of the study population

Parameter Tested	N	Mean ± SD
Fat (%)	207	25.381 ± 8.7679
Fat Mass (Kg)	207	11.848 ± 6.5769
Fat Free Mass (Kg)	207	31.854 ± 4.0287
Muscle Mass (Kg)	207	30.053 ± 3.7386
Total Body Water (Kg)	207	23.409 ± 2.9866
Total Body Water (%)	207	54.629 ± 6.4558

An analysis of the data to study the correlation of the different parameters of body composition using Karl Pearson's Coefficient of Correlation (Table 8) revealed that there was a significant association of a greater percentage of body fat, higher fat mass and consequently a lower percentage of total body water with early onset of menarche in the present study population (p value < 0.05)

Table 8: Correlation between Age at Menarche and Body Composition

Parameters Tested	Pearson Correlation		
	Pearson Correlation Coefficient	N	Sig. (2-tailed)
Fat (%)	-.040*	207	.566
Fat Mass (kg)	-.014*	207	.845
Fat Free Mass (kg)	.086	207	.217
Muscle mass (kg)	.069	207	.323

Total Body Water (kg)	.057	207	.416
Total Body Water (%)	.036*	207	.609

Studies have also shown that greater TBF, FFM and body fat higher in girls with an earlier age of menarche and onset of puberty than their later-maturing peers (Siervogel, 2003) and acquiring an optimum amount of body fat and body weight is essential for the sexual maturation of the individual which is an important factor for onset of menses.(Matkovick, 1994) the same trend is observed in our study.When a comparison was done in women who have attained menarche versus who have not attained menarche it was seen that those who had not yet started menarche had less gluteofemoral fat compared to once who had started menarche .These girls also had much lower WHR's than those with recent menarche and higher levels of total fat, suggesting that once a requisite amount of gluteofemoral fat has been stored, proportionately more fat is stored in the upper-body depots.This study also suggested that while the total estimated amount of body fat and weight are not significant predictors of menarche when added to skeletal growth, the distribution of body fat, as indicated by the relative amounts of upper-body and lower-body fat, is significantly related to menarche, especially in young women who reach this reproductive landmark with unusually low levels of total body fat. This suggests that body fat distribution may influence the timing of menarche although, alternatively, there may be a pubertal mechanism that increases lower-body fat deposition concurrent with or after menarche. (Lassek,2006)

Table 9: Discriminant Analysis of Age at Menarche with Body Composition Parameters

Age at Menarche (years)	Body Composition Parameters Tested					
	Body Fat (%)	**Fat Mass (Kg)**	**Fat Free Mass (Kg)**	**Muscle Mass (Kg)**	**Total Body Water (Kg)**	**Total Body Water (%)**
10	30.954 ± 9.4922	15.185 ± 7.0741	31.523 ± 4.1320	30.000 ± 3.6957	23.292 ± 2.9353	50.554 ± 6.9680
11	24.975 ± 9.2341	11.328 ± 6.2494	31.067 ± 3.6999	29.450 ± 3.3339	22.997 ± 2.7781	55.050 ± 6.9788
12	24.447 ± 8.0234	11.180 ± 6.1751	31.688 ± 4.0793	29.825 ± 3.8739	23.276 ± 3.0851	55.269 ± 5.8699
13	25.110 ± 8.7399	12.087 ± 7.0354	32.863 ± 4.1491	30.965 ± 3.8266	24.055 ± 3.0394	54.810 ± 6.3945

14	28.292 ± 10.2389	13.215 ± 7.0699	30.792 ± 3.4649	29.062 ± 3.1834	22.546 ± 2.5323	52.508 ± 7.4944
Total	25.381 ± 8.7679	11.848 ± 6.5769	31.854 ± 4.0287	30.053 ± 3.7386	23.409 ± 2.9866	54.629 ± 6.4558

The discriminant analysis of the age at menarche with the body composition parameters also corroborates the outcome of the analysis of the correlation between age of onset of menarche and body fat percentage. Girls aged 10 years (n=13) having a greater body fat percentage reached menarche earlier than girls aged 13 and 14 years who had a smaller percentage of body fat (Table 9)

Adolescence growth periods extents for 2.5 to 3 years and it includes-height gain, weight gain and increase in body fat percentage. (Sidhu and Grewal, 1980; Rokade and Mane, 2009 and Warren,1980).. According to Frisch(1970) menarche occurs when a girl attains desired body fat a minimum of 17% of body weight is necessary for onset of menarche.Many studies have previously reported that taller girls and girls with more body fat have earlier menarche.Studies suggest that obese girls tend to mature earlier than normal and that "thin" girls tend to mature later. For example, a significant delay in puberty and menarche is seen in girls who are very physically active and have markedly diminished body fat.

Age at Menarche and Nutrient Intake: Nutrition has always been considered a major influential factor in pubertal growth period. Not only the quantity but also quality of food intake influences puberty (Berkey et al, 2000). Nutrition intake and storage during childhood may influence the timing of menarche through hormones such as leptin, insulin and growth factors such as Insulin-like Growth Factor I (IGF-I), all of which are involved in the regulation of growth and maturation(Parent A.S. et al, 2003).

Nutritional status and body weight play a vital role in the timing of pubertal development in female adolescents(Bau A.M.et al 2009; Davison K.K.et al 2003; Slyper A.H.2006). Adolescents gain 50% of adult weight and more than 20 % of their adult height during this period (Bharati P, Bharati S., 1998). It has been suggested that decrease in the age at menarche until the mid-1960s resulted from "positive" changes, such as better nutrition,

whereas decreases since that time are related to “negative” changes, such as overeating and decreased physical activity (Paula J.W. et al 2008).Kulin H.E. et al (1982) compared between 342 privileged, urban children and 347 impoverished rural adolescents in Kenya and found that chronic malnutrition leads to a delay in menarche of girls by 2.1 years. This could be attributed to the effects of chronic malnutrition in the first decade of life leading to stunting as the mean height differences of 7.4 cm was found in both the groups in their pre pubertal stages in spite of catch up growth in early years.

In the present study information data regarding nutrient intake could be collected only from 168 subjects out of the total study population of 207 subjects, using the 24-hr record. The carbohydrate, protein, fat and total energy intake were calculated using the food value tables. The mean intake of the above-mentioned nutrient intakes are presented in table 10:

Table 10 : Nutrient Intake of the study Population:

Nutrients	**N**	**Mean ± SD**
Energy (Kcal)	168	1458.15 ± 373.716
Carbohydrates (gm)	168	198.5526 ± 59.7630
Proteins (gm)	168	43.94 ± 14.646
Fats (gm)	168	58.77 ± 18.841

Analysis of the data of the present study population to study the correlation between dietary intake and age of onset of menarche did not present statistically significant (p value < 0.05) findings as is obvious from table 11.

Table 11: Correlation between Age at Menarche and Nutrient Intake

Parameters Tested	Pearson Correlation		
	Pearson Correlation	N	Sig. (2-tailed)
Energy (kcal)	-.030	167	.698
Carbohydrates (gms)	-.041	167	.600
Proteins(gms)	-.066	167	.395
Fats (gms)	-.006	167	.936

The discriminant analysis, however, brought out the fact that girls from the 10-12 years had mean nutrient intakes similar to older girls who reached menarche later, indicating that higher nutrient intakes may be the reason for the early onset of menarche in them (Table 12)

The mean fat intake of the study population was much higher than the RDA prescribed by the Expert Group of the Indian Council of Medical Research 2009 .i.e. approximately 35 – 45 grams / day indicating that visible dietary fat contributed to a substantial contribution to the overall energy intake throughout the day.

Studies have shown that delayed menarche is a sign of malnutrition and as nutritional status improves, the age at menarche is lowered drastically.(Abioye-Kuteyi, 1997; Acharya,2006) .

Under nutrition subsequently leading to poor health have been considered as reason for the late onset of menarche as well, late onset of menarche can be attributed to low dietary intake of carbohydrate fats and proteins and overall poor health. (John, 2008). Meyer et al (1990) reported that higher dietary energy intake was associated with earlier menarche also

Table 12 : Discriminant Analysis of Age at Menarche with Nutritional Intake (macronutrients)

Age at Menarche (years)	N	Nutritional Intake			
		Energy (kcal)	Carbohydrate (gm)	Protein (gm)	Fat (gm)
10	12	1444.08 ± 312.371	24.7583 ± 48.3113	44.28 ± 11.046	55.98 ± 10.878
11	26	1443.08 ± 412.046	210.9962 ± 59.3743	43.26 ± 15.883	58.98 ± 19.876
12	68	1496.16 ± 393.567	198.7019 ± 65.3677	46.06 ± 17.159	59.67 ± 20.069

13	50	1429.16 ± 349.883	194.8974 ± 57.3683	42.10 ± 11.256	59.09 ± 18.612
14	11	1405.91 ± 361.461	199.3345 ± 54.8483	40.38 ± 11.811	54.36 ± 18.492
Total	168	1458.15 ± 373.716	198.5526 ± 59.7630	43.94 ± 14.646	58.77 ± 18.841

Merzenich et al (1993) have reported that higher energy and fat intake was associated with early age of menarche. Some studies in the past have also shown, to the contrary, that higher intakes of carbohydrate in girls aged 6–15 y were associated with a later timing of menarche.(Kissinger, 1997 ;Cheng, 2010.)

Studies have also reported that non vegetarians tend to attain menarche at an early age as compared to vegetarians (Bagga.A and Kulkarni 2000). According to Gunther(2009) higher total protein intake in girls is associated with the early attainment of menarche. Some other researchers have suggested that greater intake of milk or milk-related nutrients such as calcium, protein, or fat have contributed to earlier menarche. (Chevalley, 2005; Berky 2000). June(2003) suggests that milk may be related to its contribution to somatic growth and other mechanisms related to reproductive maturation or it may act via a common pathway (eg. IGF1 pathway) as IGF is involved in somatic growth and reproductive maturation)

It would therefore be worthwhile to study the dietary intake in greater detail using a 3 or 7 day food record validated by a food frequency questionnaire to obtain a better insight in this aspect. Also, though the number included in the present study is definitely its limitation, the data analysis does corroborate findings of many workers in this area of female reproductive health.

SUMMARY AND CONCLUSIONS

The present study was a retrospective study conducted on a sample of 200 school-going girls from two major metropolitan cities, namely, Mumbai and Pune. The girls included in the study had attained menarche less than three months prior to their inclusion as a part of the study. The study was conducted with the aim of studying dietary intake and body composition as determinants of age of onset of menarche.

- A general questionnaire was used to obtain demographic details of the selected subjects. It also included questions regarding their menstrual details such as age of onset, duration and regularity of menstrual cycles.
- The anthropometric indices such as height (cm), weight (kg), waist circumference, hip circumference were measured and BMI (kg/m^2) and waist-to-hip ratio were calculated. Data regarding the food intake was obtained using a 24-hour record along with a food frequency questionnaire for its validation. Intake of carbohydrates, proteins, fat and total energy were calculated using the food value tables.
- Body composition analysis was conducted using a Body composition analyzer (Tanita model no. BC 420 P MA) which works on the principle of Bio electrical impedance. The values and measurements for the following parameters (Kg), Fat mass(kg), Fat percentage, skeletal muscle mass total body water (kg and percentage) were made.

The data was analyzed using Frequency, mean and standard deviation for the general questionnaire, Correlations using Karl Pearsons' Coefficient of Correlation for determining the relationships between age at menarche and body composition and age at menarche and dietary-intake.Regression and Discriminant analysis to predict the age at menarche from dietary intake and body composition.

Statistical analysis of the data presented the following findings:

- Of all the anthropometric indices, height (cm) was significantly correlated (p value < 0.05) with an early menarche in the present study population. Other anthropometric parameters showed no such association.
- Body composition data analysis indicated that body fat (%), fat mass (kg), and total body water (%) was significantly correlated (p value < 0.05) with early menarche.
- Nutrient intake data also did not show any statistically significant (p value < 0.05) association with age of onset of menarche.

However, discriminant analysis of the effect of dietary intake and body composition on the age at menarche showed that though the results were not statistically significant, girls who had attained menarche earlier (10 – 12 years) were having body composition parameters and nutrient intake levels almost similar to girls who had attained menarche when they were older (13 - 14 years).

The present study has inherent limitations in not having a larger sample size and a not so accurate record of dietary intake but it has been able to bring out some important aspects regarding the relationship of dietary intake and body composition on the age of onset of menarche with respect to stature and body fat percentage of the subjects.

If such a study is conducted on a more elaborate sample, it is possible that more facts can be elicited with a greater degree of accuracy to make a valuable contribution to this very important aspect of adolescent health

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APPENDIX – A

Letter to the Principal

To,

Respected Madam,

I am happy to introduce myself as Ms. Amrita Behel, Assistant Professor in Foods and Nutrition in Smt. SPN Doshi Women's College, Ghatkopar for the past 4 years. Presently I have taken up a minor research project under UGC sponsorship titled "Determinants of Age at Menarche – Diet and Body Composition."

This study is being undertaken to assess the body fat percentage as well as muscle and fat percentage in school-going girls along with their food habits since these parameters have an influence on the age at menarche. Age at menarche is important from the point of view of future reproductive health as various research studies have shown that girls maturing early are at risk of diseases such as breast cancer, cardiovascular diseases, diabetes, etc. Hence through this study we want to establish present age at menarche of Indian girls and effect of various factors on it. Through this study girls body composition will be assessed using a hi-tech specialized Body Composition Analyzer (Tanita model no. BC 420 P MA) which works on the principle of Bio electrical impedance.. The cost of the assessment will be entirely borne by the researcher. The findings of this project will not only make the girls and their parents aware about their body and health profile in their recent future but will also give them insight about how to remain healthy, eat balanced diet and thereby to perform to their maximum potential .

This study will involve data collection from 200 students. Some of them will be selected from your institution. We want to clarify that no incidental expenses will be paid to the volunteer for participating in the study. Participation in this study is entirely voluntary but is immensely beneficial to the girls. Hence I request you to encourage maximum participation.

We are looking forward to your kind co-operation for the smooth conduct of this project. The logistics of the study are attached herewith.

Thanking You,

Ms. Amrita Behel

Logistics

1. 1st meeting with the students(5th to 9th standards Girls only) :
   Preparatory talk followed by filling up the Pre-questionnaire (screening), Sending Consent forms home to be signed by the parents.

2. 2nd meeting with the selected students :
   Collection of Consent Forms and Body Composition Analysis with anthropometric measurements such as Height, Weight, Waist Circumference, and Hip Circumference.

3. 3rd meeting with the mothers:
   Filling up the proformas; namely General Questionnaire, Food Frequency Questionnaire, 24hour diet recall

APPENDIX – B

PRE-QUESTIONNAIRE (for Screening)

NAME: _____

DOB: _____

AGE: _____

NAME OF THE SCHOOL: _____

STANDARD: _____

DIVISION: _____

CONTACT NO: _____

Please answer the following questions by putting a tick in the checkbox.

1. Have you started periods/menses?

- o Yes
- o No

2. When did you start your periods?

Date ; ___ Month:___ Year:___

APPENDIX – C

Part A

Dear Parent,

I am happy to introduce myself as Ms. Amrita Behel, Assistant Professor in Foods and Nutrition in Smt. SPN Doshi Women's College, Ghatkopar for the past 4 years. Presently I have taken up a minor research project under UGC sponsorship titled "Determinants of Age at Menarche – Diet and Body Composition."

This study is being undertaken to assess the body fat percentage as well as muscle and fat percentage in school-going girls along with their food habits since these parameters have an influence on the age at menarche. Age at menarche is important from the point of view of future reproductive health as various research studies have shown that girls maturing early are at risk of diseases such as breast cancer, cardiovascular diseases, diabetes, etc. Hence through this study we want to establish present age at menarche of Indian girls and effect of various factors on it. Through this study girls body composition will be assessed using a hi-tech specialized Body Composition Analyzer (Tanita model no. BC 420 P MA) which works on the principle of Bio electrical impedance.. The cost of the assessment will be entirely borne by the researcher. The findings of this project will not only make the girls and their parents aware about their body and health profile in their recent future but will also give them insight about how to remain healthy, eat balanced diet and thereby to perform to their maximum potential .

This study will involve data collection from 200 students. Some of them will be selected from your institution. We want to clarify that no incidental expenses will be paid to the volunteer for participating in the study. Participation in this study is entirely voluntary but is immensely beneficial to the girls. Hence I request you to encourage maximum participation.

We are looking forward to your kind co-operation for the smooth conduct of this project. The logistics of the study are attached herewith.

Thanking You,

Ms. Amrita Behel

Part B

I have been invited to participate in research conducted by Ms. Amrita Behel, Assistant Professor in Foods and Nutrition in Smt. SPN Doshi Women's College, Ghatkopar. I understand that it will involve collection of information about frequency of the consumption of variety of the foods and measurement of height, weight, waist and hip circumference and the menstrual details. I have been provided with the name and contact of the researcher who can be easily contacted. I have read the foregoing information, or it has been read and informed to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction.

With full knowledge of all these details, I agree to me and my daughter's participation in this study.

Participant Name :_____

Participant Signature : _____

Parent's/guardian's Name : _____

Parent's/guardian's Signature: _____

APPENDIX – D

Invitation for the Meeting

Date: _____

Respected Mothers,

As you are already aware we have enrolled your daughter as one of the participants in our research study. This study is going to benefit your daughter in many ways. You will get an insight into your daughter's health/reproductive profile along with diet, physical well being and academic excellence. To be able to achieve these benefits we would like to interact with you and hence invite you for a meeting for an hour.

Date**:**

Time:

Venue**:**

During this meeting we intend to complete the following:-

1. Briefing of the Research and clarification of doubts
2. Collection of information

We thereby request you to attend the meeting and kindly co-operate for the smooth conduct of this project.

In case the schedule of the meeting is not convenient to you kindly get back to us on the following number so that alternative arrangements can be made.

Contact no: Ms. Amrita Behel - 9869 36 14 56

Thanking You,

Ms. Amrita Behel

APPENDIX – E

GENERAL QUESTIONNAIRE

Name of the student: _____

Date of birth: _____ Age: _____Std: _____ Div: _____

Residential address:

_____

_____

Telephone/mobile number: _____ Email Id: _____

Occupation of father: Service□ Business□

Occupation of mother: Service□ Business□ Homemaker□

Monthly family income: Below Rs 15,000 □

Rs 15,000 – less than Rs 25,000 □

Rs 25,000 –less than Rs50, 000 □

Rs 50,000 – less than Rs75, 000 □

Above Rs 75,000 □

Is there a family history of: Diabetes Mellitus □ Hypertension □

Obesity □ Thyroid disorders□

Any other, please specify: _____

(Restrict your answer up to one generation)

Please enter your daughters known medical problems in the table below along with the medications including insulin, Over-The Counter Medication, Vitamin and Mineral Supplement, Herbal Preparations etc

Type of Medical problem	Duration in months/years	Prescribed Medicines

Q. 1 Record of your daughter's menstrual details:-

a. Age of appearance of first menstruation

9 yrs□ 10yrs□ 11yrs□ 12 yrs □ 13yrs□

b. Regularity of menstrual cycle
Regular□ Irregular□

c. Number of days of Menstrual cycle
Less than 28 days□ 28 to 30 days □More than 30 days□

d. Number of days of menstruation

Less than 4 days□ 4 to 6 days□ More than 6 days□

APPENDIX - F

24 HOUR DIET RECORD

Sample Menu

Meal	***Timing***	***Food eaten***	***Amount***	***Size***		
				Small	***Average***	***Large***
Early morning	6am	Milk	1 glass		✓	
Break fast	7am	Bread Butter sandwich	2 slices		✓	
		Almonds	5		✓	
Lunch	11:30am	Roti	1		✓	
		Sprouts Usal	1katori		✓	
		Grated carrot	1	✓		
Snacks	3:30pm	Milk	1cup	✓		
		Poha	1 medium katori		✓	
Mid evening	5pm	Apple	1			✓
Dinner	8pm	Rice	1 katori	✓		

		Fish/Chicken curry/Dal	1 medium katori		✓	
		Roti	1		✓	
		Spinach/cabbage vegetable	1 katori	✓		
Bed Time	9:30pm	Milk/Buttermilk	1 glass		✓	

24 HOUR DIET RECORD

Students name:

Std:

Meal	***Timing***	***Food eaten***	***Amount***	***Size***		
				Small	***Average***	***Large***
Early morning						

Break fast						
Lunch						
Snacks						
Mid evening						
Dinner						

Bed Time						

FOOD FREQUENCY QUESTIONNAIRE

Name: **Class:** **Div:** **School:**

Food Item	**Amount (Number)**	**Daily once**	**Daily Twice**	**Weekly Once**	**Weekly Twice**	**Once in 15 days**	**Once in 30days**	**Calculation**
MAIN FOODSTUFFS								
Chapati/Roti (with soya flour)								
Chapati/Roti (with out soya flour)								
Phulka								
Paratha								
Thepla								
Thalipeeth								
Puri								
Bhakri (Bajra)								
Bhakri (Jowar)								
Bhakri (Ragi)								

Plain Rice								
Moongdal Khichdi								
Veg Pulav/Fried Rice								
Plain Dal thick								
Plain Dal thin								
Dal with vaghar thin								
Dal with vaghar thick								
Sprout usal								
Soyabean vegetable								
BREAKFAST ITEMS								
Upma								
Food Item	**Amount (Number)**	**Daily once**	**Daily Twice**	**Weekly Once**	**Weekly Twice**	**Once in 15 days**	**Once in 30days**	**Calculation**
Poha								
Idli /Dosa Chutney								
Sheera								

Bread jam								
Bread butter								
Veg sandwich								
Cheese sandwich								
Kellogs Cornflakes/chocos/ wheat flakes with milk								
Oats								
Muesli								
Any other								
SWEET PREPARATIONS								
Wheat ladoo								
Besan ladoo								
Rava ladoo								
Groundnut ladoo								
Sevai kheer								
Milk Burfi								
Coconut Burfi								

Basundi								
Gulab jamun								
Shrikhand								
Jalebi								
Pastry								
Any other								
MILK BASED RECIPES								
Tea /coffee cow milk								
Tea /coffee buffalo milk								
Food Item	**Amount (Number)**	**Daily once**	**Daily Twice**	**Weekly Once**	**Weekly Twice**	**Once in 15 days**	**Once in 30days**	**Calculation**
Milk cows								
Milk buffalo								
Fruit milkshake								
Lassi								
Buttermilk								

Plain curd								
Paneer cubes								
Ice Cream								
Any other								
PROTEIN SUPPLEMENTS								
Bournvita								
Complan								
Proteinex								
Any other								
FRIED SNACKS (all items as 1 plate)								
Batata Vada/ Batata Vada Pav								
Bhajjiya								
Kachori/Samosa/ Samosa Pav								
Vegetable Frankie								
Cheese veg Frankie								

Finger chips								
Wafers(lays,kurkure)								
Farsan								
Chivda								
Any other								
CHAAT ITEMS (all items as 1 plate)								
Food Item	**Amount (Number)**	**Daily once**	**Daily Twice**	**Weekly Once**	**Weekly Twice**	**Once in 15 days**	**Once in 30days**	**Calculation**
Pani Puri								
Ragda Puri								
Sev puri								
Dahi Puri								
Bhel								
Ragda Pattice								

FAST FOOD								
Veg Burger								
Pizza								
Pav Bhaji								
Misal pav								
Maggie Noodles								
Any other								
NON VEGETARIAN FOOD STUFFS								
Egg Boiled								
Egg Bhurji/omlette								
Egg curry								
Chicken Curry								
Fried Chicken								
Chicken Biryani								
Mutton Curry								
Mutton kheema								

Mutton Biryani								
Fish Curry								
Fried Fish								
Fish Biryani								
Any other								
Food Item	**Amount (Number)**	**Daily once**	**Daily Twice**	**Weekly Once**	**Weekly Twice**	**Once in 15 days**	**Once in 30days**	**Calculation**
Nuts								
Plain Biscuits								
Cream Biscuits								
Chocolates								
Aerated Drinks								
Fresh/Ready made FruitJuices								