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Causative Factors of Early Menarche – A Narrative Review

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***Abstract*: *Background:* Over the past century, the average age of menarche has decreased. Female biology, as well as genetic, environmental, sedentary lifestyle, and especially dietary variables, all affect the timing of menarche. Adolescent girls menstruate on average at 12.5 years old. We have reviewed articles that discuss the various causes of early menarche in this study. Objective: Review the studies done on causative factors associated with the onset of early menarche. *Methodology:* Study design: Narrative Review of literature. *Study setting:* Google Scholar, Research Gate, PubMed Health. *Criteria for Article collection:* Articles from 2010-2021. (Relevant to keywords), Number of articles: 20 Articles, Study duration: 3 months. *Result:* On general observation socioeconomic status, BMI, nutrition and physical activity levels are among the major factors that cause early menarche. However, as almost all of the factors are heavily influenced by each other either directly or indirectly and therefore we cannot pick one or a few factors to be the most significant.**

***Keywords*: Early Menarche, Genetics, Hormones, Obesity, Sedentary lifestyle.**

1. Introduction

Menarche, also known as the first menstruation or menstrual bleeding in female humans, is a significant development milestone for females since it marks the beginning of their reproductive potential. Menarche, a late occurrence in puberty marked by breast expansion and pubic hair formation, often occurs 2-2.5 years after pubertal commencement. The initial cycles typically lack ovulation and vary considerably in length. They are usually painless and occur abruptly. It is highly challenging to calculate the average age of menarche globally because it varies so widely by geographic location, race, ethnicity, and other factors. It has been estimated to be 13 [1] by different studies and observations. Early menarche is defined as the onset of menstruation before the age of twelve. [2]

The average age of menarche has decreased over the last century, and genetic, environmental, and female biology, particularly nutritional factors, all play a role in when it occurs. During the year of 1840, the typical menarche age was sixteen and a half years; but these days, it is thirteen. In contrast, the age during menopause has held steady at about fifty years. As a result, the amount of time that women are exposed to endogenous oestrogen has increased. [3] Menarche at a young age has been linked to a variety of health problems in childhood, including eating disorders, type 2 diabetes, metabolic syndrome, breast cancer, cardiovascular disease, and overall mortality. [4] Early menarche has also been related to low-birth-weight babies [5] and spontaneous abortion. [6] One of the factors that could contribute to the occurrence early menarche is being overweight or obese.[7] Higher BMI and increased subcutaneous fat levels in the body at the age of five to nine years have been linked to an higher risk of earlier menarche.[8] Menarche typically happens delayed in athletes, such as dancers, than in comparison to the general population, with swimmers in specific being an exception, suggesting that strenuous physical activity causes delaying of puberty.[9] Since the turn of the 20th century, the majority of industrialized and emerging nations around the world have noted a secular decline in the age of menarche.[2] However, Huge spatial differences in menarche age, has been recorded, both within and between sub-national population groups. For example, the mean menarcheal age in developing nations ranged from 12.38 in China to 16.2 in Nepal, 15.8 in Bangladesh, 14.3 in India (Punjab), 13.5 in Sri Lanka, but developed nations it ranges from 13.3 in Great Britain, 13.05 in France, and 12.8 in the United States. [10]

According to a study on paleoanthropological research, prehistoric girls reached puberty at the same time as modern girls. Due to the worsening of living conditions, a large delay in the age at menarche occurred during the beginning of the modern era, just after the industrial revolution. The age at menarche did however, dramatically decline in the 20th century, particularly in the second half, as a result of the improvement in socioeconomic conditions. These days, this trend in the West seems to be slowing down or levelling out.[11] However this particular information does not have sufficient evidence, it's only based on an approximate estimation.

We have reviewed the articles that discuss the causes of early menarche in this study. To bring about a clear understanding of the causative factors of early menarche and how each factor is significant in their own way.

The major factors that we have taken into consideration in this review of literature are:

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1. BMI, Nutrition and Physical Activity Level
2. Birth Weight and Early Life Weight Gain
3. Genetic Factors
4. Socioeconomic Factors
5. Environmental Factors
6. Psychological Factors

These factors have been given individual attention and searched for in each paper that has been reviewed.

A. BMI, Nutrition and Physical Activity Level

1) BMI

BMI has been a very significant factor when it comes to the occurrence of early menarche. An important discovery was made in 1970 regarding the relevance of BMI and early menarche, it is known as "The Frisch-Revelle hypothesis" [12] It basically claims that an increase in BMI throughout adolescence and childhood is the most probable explanation for menarche occurring at a young age. This study has been cited by various researchers, thus adding credibility to the hypothesis. Body mass index (BMI), which measures total body weight, and numerous different assessments of fat distribution are two weight-related variables connected to age at menarche. The majority of studies found a link between high BMI in childhood, puberty, prepuberty, and an early age at menarche. Several studies focused on fat distribution, but the data on its influence on menarche age are not very consistent. The discovery of the leptin gene provided additional molecular evidence for the link between high body fat and premature sexual maturation. More on this will be elaborated under the genetic factor's subheading of this article.

A questionnaire based study with a sample of 2429 girls, who were between the ages of 9 to 16 years, each girl underwent a physical examination, including an evaluation and measurements of their height and weight.[13] BMI was calculated using the formula:- BMI = body weight/ height 2 (kg/m2).Overweight and obesity were identified using the World Health Organization's diagnostic criteria.[14] this study concluded that in comparison to their peers who have not had their menarche till the age of 13.69 years, girls who already had it before the age of 11.98 had considerably higher body weight, height, and BMI therefore,(early onset of menarche is linked to overweight/obesity in females. Programs aiming on the prevention of overweight/obesity should be targeted at girls with lower ages at menarche since they may be considered a risk group.

Many studies have been done correlating other anthropometric measurements such as waist circumference, gluteofemoral fat distribution, hip circumference.[15],[16] One study concluded that, rather than overall body fat percentage or bi-iliac breadth, the timing of menarche is connected to a higher proportion of lower body fat and a lower proportion of upper body fat. These fat stores may be internally signalled by increased amounts of leptin synthesis by gluteofemoral fat. They hypothesise that the adaptive reason for this pattern may lie in the role of gluteal thigh fat in providing a critical resource for neurodevelopment.[16] Contrarily another study stated that height of the girls has a higher influence on the early age at menarche than how influential weight/body fat is. [17] However as stated earlier there are some inconsistencies when it comes to this aspect of the BMI factor.

2) Nutrition

Nutrition is one of the most discussed factors of all the causative factors for an early age at menarche, as the kind nutrient that we consume definitely leaves an impact on our bodies, When it comes to type of nutrient that influences the age at menarche several studies have been conducted and they have similar results, consumption of animal protein such as cow milk, dairy products, meat and soy-containing foods may facilitate early menarche mostly through increased energy intake and resulting obesity or oestrogen-like action that facilitates sexual maturation and pubertal development. Other common nutrients, which including vegetable protein, fibre, and vitamin D, on the contrary, may protect against faster sexual maturation.[18] Another longitudinal study on dietary protein found that animal protein raised the risk of menarche while plant protein lowered the risk.[19] Animal protein could indeed stimulate insulin - like growth factor 1 (IGF-1), which is a major growth regulator in humans. In a long-term population-based study done on eight-year-old girls they discovered that high serum levels of IGF-I and adrenal androgens at the age of eight were associated with earlier menarche, regardless of body size.[20] These findings suggest that all these hormone levels play direct roles in the control of pubertal maturation. Recent global raise in animal protein intake as well as other changes in diet have contributed to obesity in children and lowered their age at menarche.[21] Consumption of breastmilk in infancy and early childhood is considered to be of great importance to overall health as well as reproductive health in girls, there is scientific proof that breastfeeding can support preventing obesity among children. Because of the possible connection between obesity and the early onset of menarche, breastfeeding may reduce the risk of early age at menarche, However the scientific consensus on the same has not been consistent.

Consumption of processed foods,soft drinks, fast foods and packaged junk foods have also been associated with early age at menarche. The intake of junk food by adolescent girls has an impact on the development of childhood and adolescent nutrition. Fast food is high in calories, fat, sugar, and sodium (Na), but low in fibre, vitamin A, ascorbic acid, calcium, and folate.[22] This study was conducted in an indonesian school concluded that students who eat junk food more often than twice a week are more probable to experience earlier menarche than students who eat junk food only twice a week.[22] Another study conducted on Indian children had similar results, Junk food consumption has a significant impact on the change in menarcheal age pattern. Those who consumed junk food only one day a week or less reached menarche at later ages, whereas those who consumed more than one to four days a week had their menarche earlier.[2] Human sexual maturity is influenced by nutrition. Because nutrition influences gonadotropin hormone secretion as well as its response to Luteinizing Hormone (LH). This hormone promotes the secretion of oestrogen and progesterone in the ovaries, allowing secondary sex signs to emerge more quickly than in malnourished teenage

girls. [23]

3) Physical Activity Level

Physical activity is definitely a key factor that determines the age of menarche, as majority of the population's lifestyles have become more and more sedentary throughout the decades we are not able to spend the amount of calories that we consume in a day, hence these become fat deposits in our body, and we have already seen the correlation between BMI and body fat with early age at menarche, thus low physical activity level or a sedentary lifestyle can be one of the causative factors early age at menarche. This has been documented and observed in various studies, and it also happens that intensive exercises, athletics, or high physical activity levels delay the onset of menarche in young girls. A cross sectional study that was carried out on 102 post menarcheal girls, aged 11-20, concluded that, the pattern of age at menarche amongst girls that participate in athletics during early pubertal ages is distinctive from the pattern amongst girls who started partaking in athletics only after menstrual cycle began. Regular physical activity throughout early pubertal ages may lower the number of girls who menstruate fairly early (11 years) and thus mitigate harmful health impacts linked to an early menarche in later life.[24] An observational study that followed young girls who took part in sports activities found that menarche typically happens delayed in athletes, such as dancers, than in comparison to the general population, with swimmers in specific being an exception, suggesting that strenuous physical activity causes delaying of puberty. The most reasonable reason for why swimming athletes do not have a decrease in menarcheal age would be that their normal body fat content counteracts the negative impacts of intense exercise on GnRH synthesised in the hypothalamus.[25] The reason for this delay was explained in another article, adolescent sports girls may experience delay in puberty as a result of reduced leptin production, that causes primary hypothalamic amenorrhea for at least 50% of the sports girls. [26] The studies discovered that the reduction in the menarcheal age pattern is strongly impacted by lifestyle choices, whether they are active or sedentary. A sedentary lifestyle is one in which the individual spends most of their time lying down or seated while engaging in activities such as reading, chatting, watching TV, playing video games, or using a mobile or desktop computer. It has been noticed that most teenage and adolescent people today prefer to engage in sedentary behaviours during their free time. This is primarily attributable to the industrialization and technological advancement in recent times; for instance, the majority of tasks that humans used to complete physically while using energy have been replaced by machinery and contemporary devices like washing machines for clothes, vehicles for commuting, vacuum cleaning, games consoles, etc. As a consequence, the amount of physical activity has decreased, resulting in a sedentary lifestyle and less time spent doing it each day. Because of this, people have plenty of free time, which they use to watch tv and use their smartphones. Endogenous oestrogen levels are decreased by exercise, but there are very few studies that have examined how exercise affects how estrogens are metabolised, and those that have examined the effects of sedentary behaviour on oestrogen metabolism are even more uncommon. An experimental study conducted in an Indian setup concluded that individuals who had a sedentary type of lifestyle attained menarche early compared to those who had an active lifestyle.[2] One study discovered that greater activity resulted in high oestrogen metabolism and excretion with lower endogenous oestrogen levels, however sedentary lifestyles, which involve decreased activity, result in high levels of endogenous oestrogen. [27]

B. Birth Weight & Early Life Weight Gain

1) Birth Weight

Birth weight is among the important factors influencing the age at menarche, yet there is substantial uncertainty about this correlation. Intrauterine growth restriction is a condition in which the foetus is unable to achieve a genetically determined body size because of a pathological process leading to chronic hypoxia; this can also additionally cause untimely menarche, polycystic ovary syndrome, and infertility. Girls born small for gestational age had an earlier age of menarche than those who have been appropriate for gestational age. The small for gestational age and appropriate for gestational age had no distinctive distinction in BMI and levels of androgens in the prepubertal stage.[28] This typically supports the speculation that girls who were small for gestational age would have an earlier age at menarche.[29] The proposed mechanism could be connected to the elevated serum level of androgen, dehydroepiandrosterone sulphate, at adolescence, which has been reported to be inversely associated to birth weight. The elevated level of dehydroepiandrosterone sulphate in babies who are small for gestational age is closely attributable to premature sexual maturity and it may impact adrenal androgen production in adults.[30] A low birth weight could be due to three conditions: intrauterine growth restriction, small for gestational age, and preterm birth. These three conditions use multiple pathways so, as a result, could have varied effects in terms of menarche age. [18]

2) Early Life Weight Gain

As we have already seen the correlation between earlier age at menarche and BMI, early life weight gain is important to consider as BMI cannot be calculated for infants who are under the age of 2 years.[31] Early life weight gain and increased adiposity may promote sexual maturation and age at menarche through a variety of pathways.[32] Various adipocytokines are produced by adipose tissue and it may alter the menarcheal age. And it's also important to note that, while greater weight increase from birth to 2 years of age was related with earlier menarche in the majority of the studies assessed, a negative association was identified for weight gain in the first 2 to 4 months of life when analysed individually. Weight rise, on the other hand, remained consistently related with earlier menarche when the time period examined lasted from birth to 6-9 months of age.[32] According to other research, high early infancy weight gain between birth and age 2 months as well as between 2 and 9 months was associated with earlier menarcheal age and it predicted future greater adiposity, as measured by a DEXA scanning at 10 years of age. However, if weight gain happened

later in infancy, between 9 and 19 months of age, this correlation was not present. [33]

C. Genetic Factors

Certain characteristics are carried from parents to their offspring through genes. Age at menarche appears to be one such characteristic that is carried over, it may not be as significant as the other factors but there have been correlations done in between maternal age at menarche and age at menarche of their daughters [2] and also correlations of age at menarche between siblings [34] have been noticed in our observation. Age at menarche is impacted by genetics, however it is unclear what precise genetic factors play a role in this. Studies have shown a tendency for maternal age at menarche to predict daughter's age at menarche to provide evidence for genetic influences on the menstrual age.[35] The daughter's age at menarche is earlier compared to the mother's age at menarche in most of the observations, this again shows the secular trend in decline of age at menarche throughout the generations and there is a positive correlation between daughter's menarcheal age and that of the mother's this was seen in an Indian observational study with a sample size of 246 girls aged between 10 to 16 years.[36] The menarcheal ages of mothers and their daughters were shown to be positively correlated, and the link lasted for up to 12 years. From that point on, it was discovered that girls started menstruating earlier than their mothers. The improved state of health may be responsible for this.[36] In another observational cross sectional study with 258 menstruating girls of the age 10 to 16 years, that conducted in India showed a strong association between the subject's age at menarche and their sister's menarcheal age. [34]

There are also studies that have made correlations between specific genes and their implications on age at menarche. One article described the Kiss1 gene, which generates Kisspeptin, and its receptor, G Protein Coupled Receptor 54 (GPR54), which plays an important role in menarche onset, reproduction, and regulates the onset of puberty. A LIN28B single nucleotide polymorphism on chromosome 6 has recently been linked to early menarche.[25] The leptin gene is related to higher body fat levels and earlier age at menarche as the leptin hormone that is produced in the hypothalamus is responsible for the pulsatile secretion of gonadotropin-releasing hormone, which serves as a signal for the beginning of menarche.[37] However a review that was done on the specific genes that are responsible for impacting menarcheal age concluded that The genetics of menarche and its timing are still being studied. The challenge of identifying the genetic factors supporting this feature has received a lot of attention over the past ten years, with notable findings being attained, but it is still far from being resolved. The ultimate objective of finding genes and their variations contributing to menarche and its start, however, is now possible due to developments in contemporary sophisticated technologies and the use of the systematic approach. [38]

D. Socioeconomic Factors

There has been a definitive improvement in the socioeconomic status and living conditions of the general population, which is mainly due to industrialization and urbanisation and thus there is change in lifestyle of the families and therefore it could impact the timing of menarche. Menarche age may also be influenced by socioeconomic factors or life circumstances, like urban or rural domicile, family type, household income, and parental education level. Girls from higher socioeconomic position families go through menarche earlier than girls from lower socioeconomic status families. [25] Girls living in urban areas typically reach menarche earlier than any of those living in rural regions.[39] A study that was conducted in the urban and rural areas of India documenting 150 girls between the age of 10 and 19 years that were randomly selected, recorded that mean menarcheal age increased with decrease in income of the household, this supports the idea that people from higher socioeconomic groups have their menarche earlier compared to them who are of lower socioeconomic status. [40] Another article that documented 355 girls noticed that earlier menarche occurred in school going students as compared to those who did domestic work and they also made a correlation where earlier menarche was seen in girls who were living with their parents than in those who did not.[41]

An Indian study that used a scale called modified kuppuswamy scale for assessing the socioeconomic status of people, observed that the age at menarche was earlier in higher classes and later in lower classes [36] Similar trends were observed globally where the decline in age at menarche occurred at a faster rate in high income countries. [39]

E. Environmental Factors

There are several hazards, pollutants and toxins present in the environment, however they do not occur naturally in fact they are also a result of industrialization as there are many factories and manufacturing plants that release these toxins into the environment, these then interact with our systems and impact our health, including the change in age at menarche. Numerous articles concentrates as to how these environmental chemicals, often known as endocrine disruptor chemicals affect the timing of puberty. endocrine disruptor chemicals are employed in plastics (bisphenol A (BPA), plasticizers (phthalates), pesticides (methoxychlor, chlorpyrifos, dichlorodiphenyltrichloroethane (DDT), fungicides (vinclozolin), and medicinal agents; diethylstilbestrol (DES) and also industrial solvents and lubricants. [42] Some endocrine disruptors, like vinclozolin, interact with the androgen receptor, while others, like fadrozole and ketoconazole, block either aromatase or steroidogenesis, depending on whether they share structural similarities with oestrogen. Endocrine disrupting chemicals may also influence puberty through regulating the Central nervous system. For instance, atrazine reduces the levels of LH and prolactin in the bloodstream, delaying maturation in both males and females. [43] One of the most widely common heavy metals is lead, that can be found in paints, lead tubes, toxic waste, and fuel that contains lead. By suppressing IGF-1, it can have an impact on female growth during puberty. Low exposure to lead may cause menarche to begin earlier, whereas high exposure may cause menarche to occur later. [44] Some cosmetics, such as hair care products,

used regularly during childhood can cause menarche at an early age. [45] Secondhand smoke is more widespread and has been investigated as a postnatal factor influencing sexual development. Nevertheless, the outcomes are ultimately unclear. [18] A study that spoke about the potential for climate change to impact women's health stated that Menarche timing may be impacted by climate change in a number of ways. Rise in the number of cyclones, tornadoes, avalanches, as well as other extreme weather occurrences could be a specific consequence. This might then cause the discharge of chemicals into the environment to increase. As we previously noted, a variety of chemicals are known to alter menarche timing. Weather conditions could also alter the availability of crops and the amount of protein and vegetables consumed, which is known to affect the onset of menarche. As a result of these variations in menarcheal age, there may be an increase in the number of disorders affecting bone health, cardiovascular health, mental health, and fertility. [46]

F. Psychological Factors

Psychological factors are those that deal with mental health of the girl children, stress and anxiety are one of the main psychological factors, these factors tend to create imbalances in our normal hormone levels and therefore have an impact on the age at which menarche occurs. This factor may be new and underrated compared to the previously reviewed factors but it's definitely very important as it deals with the mental well being of young girls. Lack of biological father is the most common psychological problem that is directed towards early menarche, many studies were done on the same including a meta-analysis. [47] It was also seen that the presence of half- and step brothers is associated with early menarche, while the presence of sisters, especially older ones, in the home when growing up was related with delayed menarche.[48] A Girl's sexual and reproductive development may be accelerated by family disturbance, childhood trauma, and ongoing stress. Family disputes can have negative effects on a child's behaviour, especially if it occurs in the first 5-7 years of life and results in reckless behaviour, teenage pregnancy, drug abuse, or early first sexual relationships. Single parenting and difficult family circumstances may hasten a girl's reproductive maturity. [21] Childhood negative experiences, like sexual abuse, are other psychological elements. Early sexual maturity is closely correlated with childhood traumas such a father who abuses alcohol, a mother who experiences anxiety, and sexual abuse. Also, physical abuse might accelerate sexual maturation. [49] One study stated that girls who experience menarche early and are sometimes victims of peer sexual harassment and may lack the skills required to deal with peer sexual harassment because of their emotional and cognitive immaturity. Peer sexual harassment, we believe, is an essential mediator in the relationship between early menarche and adverse psychological effects such as body image dissatisfaction, stress, and anxiety. [50]

2. Discussion

Menarche, which is a late occurrence in puberty marked by breast expansion and pubic hair formation, often occurs 2-2.5 years after pubertal commencement, it also known as the first menstruation or menstrual bleeding in adolescent girls, is a significant development milestone for females since it marks the beginning of their reproductive potential. Early menarche is defined as the onset of menstruation before the age of twelve. It is highly challenging to calculate the average age of menarche globally because it varies so widely by geographic location, race, ethnicity, and other factors. However, the average age was estimated to be 13. According to our observation, even 13 years of age at menarche seems outdated. But it is more important to observe the global secular decline of the age at menarche. During the year of 1840, the average menarcheal age was 16.5 years and since then it has been declining at a rapid rate, different at various geographical locations worldwide. This global declination of age at menarche would not be of great concern if it was not linked with negative consequences. There are several negative outcomes that have been observed to be associated with a lower age at menarche such as, type 2 diabetes, metabolic syndrome, breast cancer, cardiovascular disease, eating disorders and overall mortality. Additionally, it was also noticed that it affects the reproductive health in women with early menarche and therefore it is related to low-birth-weight babies and spontaneous abortions.

The aim of this study was to identify and understand the major causative factors for early age at menarche that influences the worldwide decline in menarcheal age. In order to make an observation we had shortlisted and reviewed 20 relevant articles and 30 other references from multiple sources to support the data mentioned in this study. Through the observations we made we found that multiple factors were responsible for lowering the age at menarche and some of these factors are directly interrelated to each other and the other factors though they were not directly related to the others but had an influence on them, for instance physical activity was directly related to BMI and so did nutrition whereas the socioeconomic factors and some psychological factors can alter the way a person lives and how they eat, therefore it is indirectly related to the other factors. We also noticed that psychological factors such as absence of a biological father are still very undervalued and given less importance compared to the other major factors. While factors like genetics and low birth weight need more studies as the data available on the same is continuously growing and changing through time. Since it is established that the early menarche has several negative health implications, steps such as improvements in lifestyle with regards to physical activity, diet, and obesity management need to be taken to work on the prevention of early menarche and therefore avoiding its complications.

3. Result

Our observation after reviewing 20 articles that were shortlisted on the basis of relevance to our study, most articles spoke about multiple factors. We discovered that nutrition and socioeconomic factors were the most discussed factors, with 9 articles containing data on both. This was followed by Body mass index and levels of physical activity which were discussed

in 7 articles each. Genetics, environmental, and psychological factors were among the lesser discussed factors, with 5 articles containing data on them. Low birth weight and early childhood weight gain were the least discussed factors, with only 3 articles containing data on them. Therefore, on general observation socioeconomic status, BMI, nutrition and physical activity level are among the major factors that cause early menarche. However, as almost all of the factors are heavily influenced by each other either directly or indirectly and therefore we cannot pick one or a few factors to be the most significant.

4. Conclusion

We found that each factor influences menarcheal age in its own significant ways. It is difficult to conclude saying one of the factors is more significant than the other since this is a global phenomenon, different factors are more significant in different regions of the world. As early menarche is related to various health conditions including psychological conditions like anxiety and depression leading to poor mental health, therefore it is very necessary to focus on prevention. A new observation made in our review was that the absence of a biological father was relatively a new factor under psychological factors that may lead to early menarche. Interventions like exercises, yoga and advice on eating habits can be recommended and can prove helpful. More studies are required for gaining a better understanding on this issue.

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