Early Female Puberty: A Review of Research on Etiology and Implications

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Abstract

The age of female puberty appears to have decreased in the United States and western countries as child health and nutrition have improved and obesity has become more prevalent. Also, environmental contaminants, particularly endocrine disruptors, may also play a role in lowering the age of puberty. Puberty at an early age increases the risk of stress, poor school performance, teen pregnancy, eating disorders, substance abuse, and a variety of health issues which may appear later in life including breast cancer and heart disease. Articles for this literature review were located using a computerized search of the databases Health Reference Center, Medline, PsycINFO, and ScienceDirect from 2000 to 2008. Also, reference lists from key published research were reviewed for relevant publications. Risk factors related to early puberty include genetics, race, maternal weight gain, premature or low birth weight, fatherlessness, environmental contaminants, obesity, and race. Maintenance or achievement of healthy weight, regular exercise, and a fiber-rich diet may delay the onset of early puberty. As the number of girls entering premature puberty increases, there are numerous risks, both physical and emotional. Health educators need to explore ways to help reduce the incidence and prevalence of obesity and address other modifiable risk factors.

Introduction

Early female puberty appears to be on the rise in the U.S. and other western countries. Puberty begins with thelarche, the first appearance of breast development, and ends with menarche, the occurrence of the first menstruation. Though both thelarche and menarche begin earlier than in the past, the age of thelarche is dropping faster than that of the first menstrual period. While the age of menarche has dropped from a mean of 17.5 years in the middle of the 19th century to 12.5 years by the middle of the 20th century, girls begin menstruating only a few months earlier today than girls 40 years ago (Carel & Leger, 2008).

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Though the age of menarche has not decreased significantly over the past 40 years, on average, girls began to develop breasts one to two years earlier during the same time frame. African American girls typically begin thelarche by age 9 compared to age 10 for White girls, though approximately 15% of African American girls and 5% of White girls begin breast budding between the ages of 7 and 8 (Slyper, 2006). Currently, around 50% of all girls in the U.S. have begun to develop breasts by age 10 and 14% by ages 8 and 9.

The typical age range for the onset of puberty is between 8 and 14 years in girls while early puberty occurs between 7 and 9, and precocious puberty generally takes place before the age of 6 or 7 (Carel & Leger, 2008). In a major study conducted in 1997, researchers determined that in a sample of over 17,000 girls, at age 3, 3% of African American girls and 1% of White girls had begun to develop breasts and/or pubic hair (Herman-Giddens & Slora, 1997). By age 7, 27.2% of African American girls and 6.7% of White girls had begun development with proportions increasing respectively to 48.3% and 14.7% by age 8. Overall, most scientists agree that the declining age of puberty among girls in the United States is a real and ongoing event (Steingraber, 2007).

The beginning of puberty involves the activation of the hormone estradiol secreted by the ovaries. This stimulation results in breast budding and continues with the commencement of menstruation. Other hormones involved include insulin and an interaction between an estrogen-type hormone, estradiol, and insulin-like growth factor.

There are many hypotheses as to why some girls mature earlier than others and why the age of puberty has apparently dropped. The most commonly believed hypotheses link inherited factors such as genetics, race, and birth weight with environmental stress, and environmental contaminants, particularly endocrine disruptors. Premature birth and growth retardation in the uterus are also linked to early puberty. Modifiable risk factors correlated to early puberty consist of specific dietary components such as a high fiber intake, body mass index, and exercise habits. Breastfeeding may also be protective as breast fed babies tend to be leaner and gain weight more slowly (Novotny, 2003). Clearly, some risk factors are modifiable and health behavior changes could slow down the decreasing age of puberty.

Whatever the etiology, early puberty poses physical and psychological risks for young girls. Girls who undergo puberty under age 10 are at an increased risk of eating disorders, obesity, low educational achievement, sexual abuse, early sexual initiation, drug and alcohol abuse, cigarette smoking, violent behavior, low self-esteem, and psychological stress. Other risks include an increased threat of cardiovascular disease (CVD) and breast cancer. There

also appears to be an association between a mother's age at puberty and the risk of breast cancer among her daughters (Barker et al., 2008).

Methods

The purpose of this paper is to review the current literature on the etiology and implications of early onset female puberty and the role of health education to reduce childhood obesity, inactivity, and exposure to environmental contaminants. The authors reviewed studies that identified linkages between early female puberty and obesity, lack of exercise, specific dietary components, smoking, and the exposure to environmental hazards, particularly endocrine disruptors. In addition, research relating early female puberty to physical disease and emotional and social risks were incorporated.

A total of 95 articles were located using a computerized search of the databases Health Reference Center, Medline, PsycINFO, and ScienceDirect from 2000 to 2008. Key words included puberty, menarche, obesity, endocrine disruptors, pubarche, and thelarche. Also, reference lists from key published research were reviewed for relevant publications. Inclusion criteria for this review included the following standards: research had to provide strong, significant, and timely evidence for the relationships under review. Articles on the interaction between early puberty and ovarian cancer and overall mortality were specifically excluded from this paper. It was unclear from the literature if early puberty itself or the risk factors associated with early puberty such as obesity increased the risks of ovarian cancer or overall mortality. A total of 41 studies were included in the final review.

Etiology

Genetically Linked Risk Factors

Several studies involving twins and the correlation between genetics and age of puberty indicate that up to 70-80% of the variance in pubertal timing can be explained by genetic factors. Familial similarity for age at puberty was studied in a sample of nearly 5,000 female twins. The authors concluded that the age at menarche is highly inherited with collective genetic factors explaining at least 70% of the true variation (Van den Berg & Boomsma, 2007). Belsky et al. (2007) assessed data from 756 children to determine if child-rearing patterns were a valid predictor of the age of puberty. The researchers found that maternal menarche was a stronger predictor than child rearing and that it is likely that a multitude of genes are responsible for the timing of the onset of puberty.

Race.

Herman-Giddons and Slora (1997) found that African American girls reached puberty earlier than White girls. It was also determined that among African American girls, menarche is earlier than White girls and that the gap between the two had increased during the past 20 years. In a study involving 67 Hispanic and African American girls, Talpade (2008) determined that Hispanic girls developed secondary sexual characteristics at a later age than African American girls. In an earlier study involving data from 225 clinicians in pediatric practices, it was found that at every age for every category (breast budding, pubic hair development, and menarche), African American girls were more advanced than Whites (Herman-Geddes & Slora, 1997).

The difference between races relative to early onset female puberty may be due to genetics or may be the result of increasing differences in body mass index (BMI) values which are linked with the onset of puberty and menarche. Nutrition, independent of BMI, may also play a role. Data suggest that African American girls' diets may differ than those of other ethnic groups. These differences, which include higher intakes of protein, meat, fats, and sugars, could contribute to an increase in the hormones linked to the onset of puberty (Talpade, 2008).

Other factors in addition to BMI may play a role in the differences between races. African American women are more likely to deliver pre-term or low birth weight babies, a risk factor for early puberty (Martin et al., 2007). African American girls may have different exposures to endocrine disrupting chemicals or other environmental contaminants related to an increased probability of living in urban areas with higher level of pollutants.

Fatherlessness.

A number of studies indicated that the absence of a father is reliably associated with early puberty while higher quality parental involvement from both parents was linked to a later age at menarche. Bogaert (2005) examined a national sample of men and women and found among both genders, an absent father at age 14 predicted an earlier age of puberty. The results suggest that father absence which is linked to early stress may impact growth and development in adolescents. Chisholm and colleagues found that early stress such as the absence of a father in the household, predicts the age of menarche (Chisholm, Quinlivan, & Petersen, 2005). In a New Zealand study, age of menarche was correlated with both poor relationships with parents and the absence of a father (Romans, Martin, Gendal, & Herbison, 2003).

Environmental exposure.

Environmental chemicals may be an issue in pubertal timing by indirectly contributing to risk factors such as low birth weight, premature birth, and/or obesity. In particular, endocrine disrupting chemicals affect the regulation of the endocrine system that directs pubertal timing (Parent et al., 2003). This system is complex and is vulnerable to disturbance by these chemicals. Endocrine disruptors are

exogenous environmental molecules that may affect the synthesis, secretion, transport, metabolism, binding, action, and catabolism of natural hormones in the body.

Over 4,000 people in Michigan were accidently exposed to polybrominated biphenyls (PBB), an endocrine disruptor, when the food chain became contaminated in the early 1970s. Researchers who followed 327 girls and women who were exposed found that girls exposed to high levels of the chemical had an earlier age of menarche than those exposed to lower levels. (Blanck et al., 2000). Puerto Rico has the highest known incidence of premature thelarche ever reported. A study conducted in 2000 found a possible association between widely used endocrine disruptors and premature breast development among Puerto Rican girls (Colon, Caro, Bourdony, & Rosario, 2000). Parent and associates (2003) found similar findings among foreign children migrating to Belgium. The children, who had a high incidence of precocious puberty, had high plasma levels of the insecticide DDT.

Hormones in the food supply.

In addition to chemicals and tobacco smoke in the environment which may impact puberty, hormones in meat and milk may also play a role. In the U.S., estradiol and other hormones are used as growth promoters in beef. A limited number of studies were located and it remains unclear whether or not consumption of this meat has an impact on the age of puberty (Aksglaedem, Juul, & Leffers, 2006). Milk may also be a concern since 1993 U.S. dairy farmers have used recombinant bovine growth hormone (rBGH) to enhance milk production. While rBGH does not end up a component of milk, treated cows secrete higher levels of an insulin-like growth factor which does find its way into the milk. This substance may play a role in regulating the onset of puberty (Parent et al., 2003).

Birth weight.

Two risks for early puberty in girls are premature birth and low birth weight (Parent et al., 2003). Both prematurity and low birth weight have multiple etiologies and include exposure to endocrine disruptors that may decrease the length of pregnancy. The specific causes for the relationship between early puberty and premature or low birth weight remain unclear though there are several theories including alterations in insulin levels that in turn affect hormonal systems (Newby, Dickman, & Adami, 2005). It is also hypothesized that infants born prematurely often gain weight rapidly after birth, which may lead to their becoming overweight, a significant risk factor for early puberty (Dunger, Ahmed, & Ong, 2006). In the U.S., since 1990, the number of low birth weight infants born has climbed 16% and premature births have risen 30% (Martin et al., 2007). About 18% of African American and 11.5% of White babies born in the U.S. are born prematurely.

Modifiable Risk Factors

Smoking.

Data collected from over 125,000 teachers in California found that compared with women who had never smoked, both current and former smokers experienced menarche at an earlier age (Reynolds et al, 2004). Windham, Bottomley and Birner (2004) determined that girls born to women who smoked during their pregnancies went through a significantly earlier menarche than girls born to non-smoking mothers. In addition, exposure to environmental tobacco smoke during childhood lowers the age of menarche by up to four months (Steingraber, 2007).

Obesity.

The tendency towards early puberty corresponds with the trend towards obesity for girls in the U.S. Children typically eat more calories and weigh more than 30 years ago and the rate of obesity during that time has tripled, especially for African American girls (Ong et al., 2007). Overall, black girls reach puberty earlier than do White or Hispanic girls likely due to their higher rates of obesity (Talpade, 2008).

While BMI in the period just prior to puberty is correlated to pubertal age, there is also evidence that rapid weight gain after birth may also influence the timing of puberty (Ong et al., 2007). This weight gain in infancy might suggest that this time of life may be a period of susceptibility linked to long-term outcomes. A study involving 863 European women aged 18 to 65 found that the age of menarche was inversely related to BMI among adults (Kazoka, 2007). The women who reached menarche before age 11 had a higher mean BMI compared to women who matured after the age of 13. These researchers determined that girls who were overweight before menarche were 7.7 times more likely to be overweight as adults.

Ong and colleagues (2007) also found that women who reach puberty prematurely are more likely to have children who are overweight. The researchers utilized a database which tracked the growth of over 6,000 children born in the United Kingdom in the early 1990s. Those children born to women who had reached early menarche were the most likely to gain significant body fat by age two and to retain it throughout their childhood.

Exercise.

During the past 30 years, girls in the United States, particularly African Americans, have been increasing less physically active. The older the girl, the less likely she is to exercise. At age 17, 50% of African American girls and about 33% of White girls are sedentary (Hardy, 2007). Exercise appears to delay thelarche primarily through its role in increasing fat breakdown and the resulting effect on the hormonal system (McMurray & Hackney, 2005). However,

while it is clear that exercise impacts the age of puberty, it is difficult to separate the effects of exercise from simply being lean or having less body fat.

Nutrition.

Specific nutrients including fiber, calcium, vitamin C, and protein may also influence pubertal timing. Koo (2002) determined the risk of early menarche for girls who ate more than 25 grams of fiber per day from fruits, vegetables, and whole grains was approximately half that of girls who consumed less than 18 grams per day. He theorized that since estrogen is known to bind with dietary fiber in the body, girls with higher fiber diets might be excreting more estrogen, which correlates to later menarche. The author also found that girls who ate higher amounts of monounsaturated fats as opposed to polyunsaturated oils in their diet experienced a later onset of menarche.

Talpade (2008) analyzed nutritional differences among African American girls who experienced early puberty. Results showed a significant difference between calcium and fiber consumption among the girls who experienced early versus later puberty. Intake of other foods showed that girls reaching early puberty had a higher fat and cholesterol intake. The author theorized that estrogen-like growth hormones and fat-like compounds found in fat and cholesterol-rich foods stimulate early puberty. In addition, protein and vitamins may also play a role in early puberty. Berkey, Gardner, Frazier and Colditz (2000) found that girls who ate more animal and less vegetable protein at ages 3-5 years had an earlier menarche while vitamin C and early puberty were inversely related.

Implications of Early Puberty

Disease Risks

Cancer.

As the age of puberty decreases, particularly the age of menarche, the overall risk for breast cancer rises. Girls who experience menarche prior to age 12 have a 50% increase risk of breast cancer compared to girls who go through menarche at 16 (Steingraber, 2007). Early puberty is linked to a greater lifetime contact with estrogens, a risk for breast cancer. In addition, early puberty frequently increases the gap between menarche and first pregnancy, a critical time period for the development of breast cancer. Finally, early puberty is correlated with a high BMI, particularly body fatness. Premature thelarche, frequently but not consistently correlated to early menarche, is both a breast and ovarian cancer risk factor in and of itself (Barker et al., 2008).

Cardiovascular disease (CVD).

The relationship between early puberty and CVD is correlated with a high BMI and body fatness (Kazoka, 2007). In addition, CVD has a relationship to insulin resistance, which may also be linked to early puberty. Specifically, elevated insulin levels cause endocrine shifts which may promote early menarche (Cordain, Eades, & Eades, 2003). In a recent study involving over 9,000 Chinese women, researchers found that the younger the age of menarche, the higher the levels of triglycerides and other markers of metabolic syndrome including blood pressure, BMI and total cholesterol, all risk factors for CVD (Feng et al., 2008). It was also determined that girls with high risk factors for CVD were more likely to go through early menarche (Allsworth, 2004).

Emotional and Social Risks

Depression and eating disorders.

Negriff, Fung and Trickett (2008) studied 213 girls age 9-13 and found that early puberty was related to depressive symptoms. Research by Stice, Presnell and Bearman (2001) found that among 496 female participants, the rate of depression among girls who matured early was approximately twice that of girls who matured later. The authors believe the elevated emotional distress may be related to the fact that early development increases the probability that girls will need to deal with a variety of stressors before they are psychologically ready. They also hypothesized that maturing before one's friends and peers may promote feelings of depression and isolation.

Premature maturation may amplify concerns girls have with body shape and weight. Early maturing girls are more likely to report body dissatisfaction and poor self-esteem during adolescence and to engage in disordered eating. It was also found that early menarche was associated with a higher rate of eating disorder symptoms and increased the risk of eating disorders (Stice et al., 2001).

Substance abuse.

A study by Storvoll, Pape and Rossow (2008) found that among over 9,000 adolescents age 13-17, those who had matured early reported more alcohol-related harm than those who had matured later. The researchers theorized that the girls' early maturity and more mature appearance increased the probability they would socialize with older-aged friends who used drugs and alcohol.

Sexual activity.

By the age of 18, girls who have experienced early menarche are more than twice as likely to date, engage in sexual relations, and become pregnant (Amy & Loeber, 2007). Romans et al. (2003) determined that the presence of an older boyfriend, more common among girls experiencing early puberty, increased the likelihood of sexual activity.

Girls who reach puberty early may also experience unwanted sexual advances and may be placed in hazardous situations with less emotional resources than older girls or

women (Stice et al., 2001). Among those who had been sexually abused as children or teenagers, there was a greater probability they had experienced early puberty.

Academic achievement.

Early maturers have a high probability of problems at school including absenteeism and truancy. These girls report less interest in academics and are less likely to go on to college. Researchers assessed data from the National Longitudinal Study of Adolescent Health and the Adolescent Health and Academic Achievement Study and found early puberty was a valid predictor of girls' grade point average and the likelihood they would fail a course at the start of high school (Cavanagh, Riegle-Crumb, & Crosnoe, 2007). It also predicted that early maturation increased the probability of dropping out of high school.

Violent and delinquent behavior.

Early puberty has also been linked to delinquent behaviors including fighting, vandalism, and shoplifting (Negriff et al., 2008). Just as a relationship with an older boyfriend or an older group of friends increases access to alcohol, it also can facilitate delinquent behaviors among early maturing girls. Overall, conduct disorders are higher among girls who mature early and these girls are disproportionately engaged in criminal activity as well (Romans et al., 2003).

Implications for Health Education

There appears to be sufficient evidence linking premature puberty in young girls with numerous deleterious outcomes related to risky behaviors and, consequently, physical, social, and emotional problems. More specifically, primary factors that this review of literature identified as being associated with early puberty can be influenced and modified by public health initiatives and/or school health education: obesity, premature/low birth weights, and exposure to endocrine disruptors. In addition, health educators may influence early sexual activity, an effect of premature puberty.

In order to influence modifiable risk factors, effective health education programs must be based on proven models and theories to assure success such as the Health Belief Model (HBM) (Rosenstock, 1990) and the PRECEDE/PROCEED Model (Green & Kreuter, 2005). The HBM explains the relationship between individuals' health behaviors and their beliefs about their own health, while the PRECEDE/PROCEDE Model can assist in planning for educational intervention, based on predisposing, enabling, and reinforcing factors influencing of the health-related problem.

Obesity and Nutrition

Constructs of the HBM as well as the Educational Diagnosis Phase of the PRECEDE Model should be used to guide intervention to improve nutrition, increase physical activity levels, and ultimately, decrease childhood obesity. Theoretical constructs can also inform interventions for improving self-esteem and body image. Health education efforts might first attempt to address and modify predisposing factors, including knowledge, attitudes, values, and perceptions, not just of children and adolescents, but their parents/caregivers, and teachers.

Emphasizing the importance and benefits of increasing physical activity and healthy eating is also an important step toward decreasing obesity and the age of puberty. One school-based nutrition and fitness program has found that participants experience menarche later than control groups (Chavarro, Peterson, Sobol, Wiecha, & Gortmaker, 2005). The Planet Health program was developed to prevent and decrease obesity by encouraging improvements in the school cafeteria menu and also fostering participation by families (Cluggish & Kinder, 2008). The program focused on decreasing high fat food intake, increasing fruit and vegetable consumption, promoting physical activity, and decreasing sedentary activities such as television watching. After a two-year period, 508 Boston-area students in the sixth and seventh grade had lower average BMIs, decreased periods of sedentary activities, and lower body fat. The girls were also a third less likely to experience early menarche during the study than those in the control group.

The relationship between negative body image and eating disorders in young people is well known and documented (Littleton & Ollendick, 2003). Research suggests that early puberty may negatively impact healthy eating behaviors, self-esteem, and body image of young girls with body image mediating the relationship between pubertal timing and self-esteem. School health education programs should use theoretically grounded instructional methods based on, for example, the HBM, to nurture positive self-esteem by altering negative beliefs and attitudes that young people have related to body image and eating behaviors.

Premature Birth/Low Birth Weight

For children born prematurely or low birth weight, breastfeeding is especially valuable since these children are prone to rapid weight gain after birth, which increases their risk for obesity and early puberty (Slyper, 2006). Breast fed infants are thinner than babies fed with formula, a difference that continues into later childhood (Novotny, 2003). All of these facts can and should be taught in an age-appropriate school health education program with the hope of altering misperceptions and creating positive attitudes and perceived benefits of breastfeeding and its importance for healthy babies. Adolescent girls and their parents can also be made aware of the accessibility and availability of resources in the community that teach breastfeeding skills, thus improving the likelihood of engaging in this preventive health behavior. Another effective intervention to reduce the number of low birth weight infants is to discourage smoking during pregnancy, a cause of growth retardation in the uterus (Reynolds et al., 2004).

Environmental Exposure

Environmental chemicals and hormones may play major roles in the onset of early puberty (Askglaede et al., 2006; Blanck et al., 2000; Colon et al., 2000). Public health and school health education efforts would help explain the risky consequences of environmental toxins, and promote specific actions that would have significant benefits. Schools and communities can take leadership roles in efforts to avoid the use of herbicides and insecticides on the school grounds and public parks and playgrounds to reduce the exposure of students to endocrine disrupting chemicals. Similarly, efforts can be made to rid schools and neighborhoods of lead and other chemicals, and encourage individuals to be tested for exposure.

Early Sexual Activity

Sex education programs which focus on the physical, social, and emotional benefits of decreasing early sexual activity, a consequence of early puberty, can enhance positive behavior change. Health education programs might also include the following related to this risky behavior: parent, peer, and societal reinforcing factors such as the media; predisposing factors such as lack of knowledge, low self-esteem, and high stress; and enabling factors such as poor decision-making and communication skills.

Conclusion

It appears that the age of puberty is decreasing in the United States and other western countries. Early puberty is a risk factor for a variety of physical illnesses including breast cancer and cardiovascular disease. It is also linked to a multitude of social and behavioral concerns such as an increased risk of substance abuse, eating disorders, early sexual activity, teenage pregnancy, poor academic achievement, and depression. Since thelarche and menarche are happening earlier and earlier, particularly among African American girls, there is cause for concern. There is a documented need for theory-based health education, based on models to address some of the underlying factors that increase the risk of early puberty including obesity, premature birth or low birth weight, and exposure to endocrine disruptors.

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