The Effect of BMI on the Age of Menarche in Adolescent Girls

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ABSTRACT

THE EFFECT OF BMI ON THE AGE OF MENARCHE IN ADOLESCENT GIRLS

by

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Title: THE EFFECT OF BMI ON THE AGE OF MENARCHE IN ADOLESCENT GIRLS

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Problem

Over the past century, the age of menarche has consistently declined in the United States and globally. Obesity has also increased by 82% globally over the past 20 years. Obesity, as measured by BMI percentiles in children, may contribute to the declining age of menarche.

Method

Adolescent girls ages 12-19 were examined in California and Michigan. Physical development and the age
of menarche were assessed through an online questionnaire. Height and weight measurements were taken at a clinic and converted to BMI percentile values.

Results

A negative correlation was observed between BMI percentile values and the age of menarche in the participants. For every increase in BMI percentile, menarche was attained 3 days earlier.

Conclusion

Obesity may play a role in the early attainment of menarche, as measured by BMI percentile values. Females with higher percentile values may attain menarche earlier than females with lower values.
THE EFFECT OF BMI ON THE AGE OF MENARCHE
IN ADOLESCENT GIRLS

A Thesis
Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Samara R. Sterling
2013
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APPROVAL BY THE COMMITTEE:

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CHAPTER 1

INTRODUCTION

Background and Statement of the Problem

Puberty with the onset of menarche represents an important transition in the life of a female from childhood into adulthood. The physiological changes that accompany entrance into the menstrual cycle allow for sexual maturity and the ability to become pregnant.

It has been well documented that the age of puberty, as evidenced by the onset of menarche in young girls, has been steadily declining over the past 100 years. In the United States and globally (with the exception of certain countries in Sub-Saharan Africa) this declining trend has been noted (Chumlea et al., 2003).

Various theories exist to explain this observation, including the improved nutritional status of families and society in general (Garden, Hernon, & Topping, 2008). There is now increased accessibility to food that was not present decades before. Yet as the nutritional status of society has improved, the problem of obesity has also increased to
a greater extent than was seen before. Obesity is now considered to be a pandemic, and as both adults and children alike are becoming more overweight and obese, the attainment of early menarche has become a concern (Komlos & Brabec, 2010).

Numerous studies have demonstrated a negative correlation between high BMI percentile values in children with the early attainment of menarche (Clark, Thornley, Tomlinson, Galletley, & Norman, 1998). An accelerating BMI percentile change in childhood is also correlated with a lower age of menarche (Oh et al., 2012). Early entrance into puberty is not without its effects upon society. Sexual maturation comes with societal pressures and consequences that a mere adolescent girl may not be mentally equipped to handle (O'Grady, 2008). This premature aging also has the potential to affect the health of the individual, with increasing the risks of certain diseases and complications (Chiaffarino et al., 2001; He et al., 2010).

**Purpose and Significance of the Study**

The purpose of this study was to assess whether higher BMI percentile values are associated with earlier
ages of menarche in young girls. Since obesity is considered a risk factor for early physical development, the self-reported age of menarche was correlated with obesity, as measured by BMI percentile values.

The contribution of this study is significant because of the implications of early menarche and the problem of obesity in the United States. Since early menarche is accompanied not only by social pressures, but higher disease risks, it is imperative that as a society possible options are explored to stabilize the acceleration of physical development that is being observed in children.

Furthermore, public awareness about the problem of obesity has increased and there is now a growing concern about the complications that are experienced with childhood obesity. If obesity contributes to an abnormally early development, it may trigger a domino effect by indirectly contributing to other issues that are associated with early menarche. Even though the rapid rise in obesity seems uncontrollable, obesity can be controlled through environmental and lifestyle changes. Implementing these changes can help to prevent the aforementioned domino effect from taking place.
Research Question and Hypotheses

This research sought to provide answers to the following questions:

Research Question 1: Is there a significant correlation between BMI percentile values and the age of menarche?

Research Hypothesis 1: There is a negative correlation between BMI percentile values and the age of menarche; adolescent girls who have higher values will experience menarche at earlier ages than girls with lower values.

Research Question 2: Is there a significant correlation between the age of menarche in adolescent girls and body fat percentage values?

Research Hypothesis 2: There is a significant correlation between the age of menarche in adolescent girls and body fat percentage values.

The main objective of this study was to examine the correlation between BMI percentile values and the age of menarche in adolescent girls in California and Michigan. The contribution of body fat measurements was also important. Therefore, Research Questions 1 and 2 were the focus of the study. However, in addition to these main questions, the contribution of ethnicity and vegetarian
status in relation to the attainment of menarche was also of interest:

*Research Question 3:* Is there a significant difference observed in the age of menarche among adolescent girls of different ethnicities?

*Research Hypothesis 3:* There is a significant difference in the age of menarche among adolescent girls of different ethnicities.

*Research Question 4:* Is there a significant correlation between vegetarian status and the age of menarche?

*Research Hypothesis 4:* There is a significant correlation between vegetarian status and the age of menarche; adolescent girls who are vegetarians will attain menarche later than girls who are omnivores.
CHAPTER 2

LITERATURE REVIEW

Introduction

Menstruation is “the cyclic, physiologic discharge through the vagina of blood and mucosal tissues from the nonpregnant uterus” (“Menstruation,” 2007). This period usually lasts for an average of 5 days and recurs approximately every 4 weeks. The cycle continues from puberty to menopause, usually between the ages of 11 and 14 through to the 40s or 50s. Menstruation can periodically stop during this time if a woman is pregnant or lactating, or because of emotional or environmental reasons (“Menstruation,” 2007).

During the first half of the menstrual cycle, estrogen levels begin to rise, which causes the lining of the uterus to thicken in preparation to accommodate a fetus. Maturity of an ovum, or egg, causes it to leave the ovary and to travel toward the uterus in preparation for fertilization from a sperm cell. During ovulation, progesterone levels
also increase to maintain the thickness of the uterine lining (Healthwise, 2011). If the mature egg is fertilized by a sperm cell during ovulation, the egg attaches to the wall of the uterus and the female becomes pregnant. If, however, the egg remains unfertilized, the egg breaks apart and estrogen levels fall. This causes the thickened lining of the uterus to be shed and blood to be discharged from the vagina during menstruation. Therefore, the menstrual cycle is intimately connected with a woman’s ability to conceive. Interruption of the cycle due to physical, environmental, or emotional factors can prevent this occurrence (US Department of Health and Human Services, 2012).

Menarche, or the point at which menstruation first begins, is considered to be the transition period at which a female exits childhood and enters into adulthood. It is a measurable marker of the onset of puberty, since it indicates that the body has developed to a point at which it is becoming sexually mature. The average age of menarche is between 11 and 14 years old for most females, with the average age being 12 years. The onset of menarche is also accompanied by breast development (thelarche) and the development of pubic hair (pubarche). The now uniformly
accepted Tanner Stages of development (Figure 1) provide visual representations of physical development by placing adolescents into five stages based on how much they have matured sexually (Vermont Department of Health, 1999).

Figure 1. Tanner stages of both breast development and pubic hair development for girls divided in 5 stages. Adapted from “Precocious Puberty,” by Jean-Claude Carel and Juliane Léger, 2008, The New England Journal of Medicine, 358, p. 2366-2377. Copyright 2013 by the Massachusetts Medical Society.

While boys are assessed based on pubic hair and genital development, girls are assessed based on pubic hair
and breast development. In an adolescent female, these changes usually accompany the onset of menarche.

Particularly during the first few years following the onset of menarche, it is common for teens to experience irregular menstrual cycles due to low or changing progesterone levels. This irregularity may result in changes in cycle length or heavy menstrual bleeding (Healthwise, 2011). Generally, however, the cycle stabilizes when the female enters adulthood. Changes in the menstrual cycle can also be caused by other factors including stress, heavy exercise, being underweight or overweight, and taking birth control pills (Healthwise, 2011).

Additionally, the onset of menarche does not always indicate ovulation in young girls. Examination of post-menarchal girls ages 7-17 showed that 80% of the girls were anovulatory during the 1st year of menstruation, 50% in the 3rd year, and 10% in the 6th year (Apter, 1980). Ovulation can be signaled by consistent and predictable menstrual flow.
Average Age of Menarche Over the Past 100 Years

There is existing evidence that the average age of menarche has been decreasing over the past 100 years (Chumlea et al., 2003). A population cohort study conducted on U.S. women by Johns Hopkins University examined the reproductive trends among women born between 1912 and 1969. It was found that the mean age of menarche consistently fell from 13.1 to 12.7 years between the years of 1920-1940, although that average age raised slightly between 1950 and 1969 to 13.0 years (Nichols et al., 2006).

Data from the second and third cycles of the National Health Examination Survey were compared from 1963-1970 and 1988-1994 to assess if there was an observable difference in the age of menarche of females in the United States. These data showed that the average age of menarche dropped from 12.75 to 12.54 years in the United States, a difference of 2½ months (Anderson, Dallal, & Must, 2003). This finding has been consistent with similar studies, therefore it is generally accepted that there has been a consistent decline in this average age. Other developed countries, such as those in Northern Europe, have also documented this trend. It is estimated that the average age of menarche in Northern Europe has declined up to 3 years.
over the last century (Bellis, Downing, & Ashton, 2006). The average age of menarche in the UK fell from 16.5 years in 1840 to 12.8 years in 2008 (Garden et al., 2008).

Presently, the median age of menarche worldwide is estimated to be 14 years (Gathani, Ali, & Beral, 2010) and 12.5 years in the United States (Anderson et al., 2003). In less developed countries, the age is later; in India the average age at menarche was reported as 15.4 years in 1998 and 16.1 years in Senegal in 1997 (Parent et al., 2003).

The factors contributing to the declining trend over the years are still not well understood. One prominent theory that seeks to explain this observation attributes the declining trend to an improvement in nutritional status of societies (Garden et al., 2008). As the availability of food increases, the nutritional status of families, including young girls, also increases, which would contribute to a more rapid physical development. Connected to this is the idea that the increasing body mass index of children over the years has contributed to this decline.

**Factors That Influence Age at Menarche**

Early menarche is commonly accepted to be before 12 years of age (Mumby et al., 2011). The Third National
Health Examination Survey of 2002 found that only 10% of U.S. girls begin menstruating before age 11, and 90% of all U.S. girls are menstruating by 13.75 years of age (Chumlea et al., 2003). It is not unheard of, however, to find some young girls who begin to menstruate as early as 8 years old. Late menarche (after 14.1 years) is possible as well (Al-Sahab, Adair, Hamadeh, Ardern, & Tamim, 2011); there are females who do not begin to menstruate until age 17. It has been determined that this wide range concerning the age at which a female sees her first period can be explained by a variety of factors, including physical factors (such as race, genetics, and birth size), environmental factors (such as exposure to pollutants or chemical toxins), and family influences.

**Physical Factors**

**Race**

The Bogolusa Heart Study conducted in Louisiana in 2002 compared the average age of menarche of Black and White girls using both cross-sectional and longitudinal analyses. The study also looked at whether or not anthropometric measurements of both groups could offer a possible explanation to any differences observed. On
average, the Black girls began menstruating 3 months earlier than the White girls did (12.3 years vs. 12.6 years). It was also found that the Black girls were taller and weighed more, which could also contribute to an earlier development. However, even after adjusting for weight and height, the Black girls experienced a 1.4-fold higher rate of early menarche than did White girls (Freedman et al., 2002).

Another study collected menstrual status data from 2510 Black, Mexican-American, and White girls ages 8-20 and analyzed the ages at which 10%, 25%, 50%, 75%, and 90% of U.S. girls attained menarche. It was found that the age at menarche was significantly earlier for non-Hispanic Black girls compared to White girls at the ages when 10%, 25%, and 50% of all U.S. girls attained menarche. Mexican-American girls were only significantly earlier than White girls at 25%. The age of menarche was significantly earlier for both Black girls when compared with the ages of menarche for White girls and Mexican-American girls (Chumlea et al., 2003). A similar study using data from the Third National Health and Nutrition Examination survey analyzed the onset of puberty among Black, Mexican-American, and White girls. Black and Mexican-American
girls not only attained menarche earlier than White girls, but they also showed earlier signs of puberty including breast development and the onset of pubic hair. At 9 years old, for example, 49.4% of Black girls had breast development, followed by 24.5% of Mexican-American girls and 15.8% of White girls (Wu, Mendola, & Buck, 2002).

**Genetics**

The contribution of genetics to the timing of the onset of menarche is in the process of being studied. Studies conducted on twins over the past 20 years have found that genetics can account for 53-74% of the variation seen in age at menarche among females (Yang et al., 2007). Another noteworthy consideration is the discovery that maternal age at menarche influences the age at which a female offspring will enter puberty. An earlier age at maternal menarche seems to present a faster growth tempo and a greater likelihood of earlier menarche for the offspring. A study done on mothers and their female offspring to compare their self-reported ages of menarche found that daughters of mothers in the earliest menarche quintile (before 11 years) were more likely themselves to report menarche before age 11 (Ong et al., 2007).
Specific genes have been identified in connection to the timing of puberty and the onset of menarche. There is evidence that leptin, the “obesity” gene, is inversely associated with the age at menarche. The leptin levels of pre-menarchal females ages 8-13 were examined for 4 years. Elevated serum leptin levels were associated with an earlier age at menarche. For example, an increase in just 1 ng/mL of leptin levels was associated with earlier menarche by 1 month. Leptin levels in females who did not attain menarche even after the 4-year follow-up period were low (Matkovic et al., 1997).

Chemokine Receptor 3 (CCR3) is a receptor for the gene that is involved in regulating endometrium-related metabolic pathways. Since menarche is the time at which a woman experiences the first destruction of the endometrium, a study was designed to investigate whether or not the CCR3 gene is also involved in the onset of menarche. The study done on 1,048 Caucasian woman found that the age of menarche was dependent on the polymorphisms of the CCR3 gene. For example, females carrying a different form of the gene, AGA, attained menarche at an average of 4 months earlier than females without it (Yang et al., 2007).
Birth Size

Size at birth, which is influenced by intrauterine growth, has been shown to affect physical development. Data collected from women in the U.K. indicated that women who were born with lower birth weights had significantly earlier ages at menarche (Morris, Jones, Schoemaker, Ashworth, & Swerdlow, 2010). Additionally, Filipino women born between 1983 and 1984 were assessed based on birth weight and age at menarche. Girls who were described as long and thin at birth (> 49 cm, > 3 kg) experienced menarche approximately 6 months earlier than girls who were described as short and light at birth (< 49 cm, < 3 kg) (Adair, 2001).

Physical Environment

The physical environment in which a fetus is exposed can present long-lasting effects on the child when it is born. This finding presents a responsibility for the mother to ensure that the environment in which the child is exposed is conducive to optimal health, both during pregnancy and throughout its life. It has been observed that the prenatal and postnatal environment of a female
(exposure to potential endocrine disrupters) may determine the age at which menarche is attained in life.

**Tobacco**

Toxins contained in tobacco smoke appear to affect the function of the endocrine system. Since the onset of menarche is controlled by the endocrine system, any disruption of this system can also affect the timing of menarche (Windham, Bottomley, Birner, & Fenster, 2004).

One study showed that female offspring of mothers who smoked more than 20 cigarettes per day during pregnancy attained menarche a few months earlier (at 12.86 years) than those who were not exposed to tobacco (13.00 years) (Windham et al., 2004). Postnatal exposure to tobacco smoke also appeared to influence the age at menarche in a study done on New York women. Females who were exposed to tobacco in-utero and in the childhood environment had significantly later ages at menarche than those who were not exposed prenatally or postnatally (>12 years versus <12 years) (Ferris, Flom, Tehranifar, Mayne, & Terry, 2010). These findings suggest that both prenatal and postnatal exposure to tobacco may interfere with the reproductive function of females.
**Polybromated Biphenyl**

Polybromated biphenyl (PBB), a manufactured chemical commonly used in plastics, was also found to interfere with the endocrine system and, subsequently, the age of menarche. Following an accidental contamination of Michigan’s food supply in 1973, the physical development of 327 girls ages 5-27 who had been exposed to PBB in-utero and after birth through breastfeeding were examined. Breastfed girls who also had the highest exposure of PBBs in-utero reported significantly earlier average ages at menarche than breastfed girls with the least amount of exposure to PBB in-utero (11.6 years versus 12.2-12.6 years) or females who were not breastfed at all (12.7 years) (Blanck et al., 2000). The results from this study indicate that a female’s exposure to PBB both in-utero and during breastfeeding has a long-term impact on the timing of menarche.

**Dichlorodiphenyl Trichloroethane**

Dichlorodiphenyl trichloroethane (DDT) is an insecticide that was used extensively in agriculture until a U.S. ban in 1972. DDT is structurally similar to various steroids, including estrogen, and it has been speculated
that exposure to it can interfere with endocrine function (Ouyang et al., 2005). A retrospective study was done to examine the serum DDT levels of 466 female Chinese textile workers ages 20-34 years between 1996 and 1998. The self-reported age at menarche was lower for women who had higher serum levels of DDT. A 10ng/g increase in serum DDT levels was associated with a reduction in age at menarche by 0.20 years (Ouyang et al., 2005).

Family Influences

Maternal Influence

It has been previously shown that maternal contributions can affect a girl’s physical development. A mother’s age at menarche influences the age at which her daughter attains menarche, and maternal (and subsequently fetal) exposure to tobacco or other toxins can also determine the age at which her daughter will attain menarche.

A mother’s level of physical activity during pregnancy has been shown to be influential. Daughters of participants from the Nurses’ Health Study who reported the highest level of physical activity during pregnancy reported an average age at menarche that was 0.9 months
later than daughters whose mothers reported being inactive during pregnancy (Colbert, Graubard, Michels, Willett, & Forman, 2008).

Evidence suggests that how long a mother chooses to breastfeed may also influence the onset of menarche in female offspring. The Cebu Longitudinal Health and Nutrition Survey of the Philippines showed that for every 1-month increase in the duration of breastfeeding, there was a decreased risk of attaining early menarche by 6% (Al-Sahab et al., 2011).

**Paternal Influence**

Although the role of a father in the development of a child is different from the role of the mother, the presence or absence of the father, either physically or emotionally, has also been shown to affect a girl’s age at menarche. The physical development of young girls ages 11-14, as observed by the onset of menarche, was assessed in relation to whether or not their biological fathers were present in their lives. Girls of fathers who were absent were more likely to attain menarche at earlier ages than girls who had fathers who were present (Maestripieri, Roney, DeBias, Durante, & Spaepen, 2004). A similar study
which yielded consistent results hypothesized that this observation might be due to a disruption of hormones like cortisol because of the stress of a father’s absence. Cortisol also plays an important role in the timing of pubertal (Bogaert, 2005).

However, a longitudinal study done on twin mothers and their female offspring indicated that a more accurate predictor of early menarche was the presence of a stepfather, even more than the absence of the child’s biological father. The presence of a stepfather could indicate a lower quality of involvement in the child’s life. Girls who had stepfathers began menstruating at an average of 12.52 years, compared with an average of 13.06 years in girls who did not have stepfathers (a difference of 6 months). Genetic factors were still seen to outweigh the effect of these environmental influences, however. The study also found that if a girl was genetically related to someone who has a stepfather, she was more likely to experience menarche at an earlier age than if she did not have a relative with a stepfather (Mendle et al., 2006).
**Childhood Experiences**

Stressful family environments can also affect a child’s physical development. Earlier ages at menarche have been noted in females who are in more stressful environments than their peers. Highly stressful environments include those in which the father is absent, poverty is experienced, and family conflicts are many. It has been observed that these environments tend to lower the metabolism and contribute to weight gain, which may help to explain the observed decrease in age at menarche (Mendle et al., 2006). Mexican-American girls who perceived their family environments as prone to conflict were more likely than their peers to attain menarche before age 11 in one study (Jean et al., 2011). Additionally, if the mothers of the girls were single, they had a twofold higher risk of attaining early menarche (Jean et al., 2011).

Children who report experiencing traumatic events, such as physical and/or sexual abuse, are more likely to report an earlier age at menarche, according to a University of Toronto study. Additionally, poor relationships between the child and either one or both parents, a “loner personality in childhood,” or experiencing family conflict, all contributed to an earlier
age at menarche (Romans, Martin, Gendall, & Herbison, 2003).

Health and Nutrition

External and relatively uncontrollable circumstances, as was previously discussed, can determine the rate at which physical development takes place. The health and nutrition of a child presents an important contribution to the onset of puberty, specifically the timing of menarche. Some aspects of health that can affect the onset of puberty, such as certain inherited diseases, are uncontrollable. Yet there are other aspects of health, including diet and exercise, which can be largely monitored by parents and children to contribute to a more natural rate of physical development.

Inherited Diseases

β-thalassemia major

Research has shown that inherited blood conditions, such as β-thalassemia major, can affect the onset of menarche in young girls. Thalassemia is a severe type of hemolytic anemia that causes an abnormal production of red blood cells and oxygen depletion. Victims of thalassemia
usually have to undergo blood transfusions to keep hemoglobin levels normal (Chen, 2012). In an observation of 250 adolescents ages 12-18 with β-thalassemia major, it was shown that there was a delay in the onset of menarche in the young girls. In fact, only 19% of all the females had experienced menarche at the time of the study (Borgna-Pignattia et al., 1985). Other forms of anemia, such as sickle-cell anemia, can also disrupt the timing of menarche by delaying its onset (Luban, Leikin, & August, 1982).

Blindness

Blindness, specifically in the lack of ability to perceive light, has also been shown to affect the onset of menarche. Impaired reproductive function usually accompanies women who have visual impairment. A study done on 1,392 blind women between 2005-2007 showed that women who had no light perception reported an earlier age at menarche (average 12.16 years) than women who had light perception (average 12.42 years) (Flynn-Evans E. E., Stevens, Tabandeh, Schernhammer, & Lockley, 2009). This study demonstrated the importance of light in triggering and generating cyclic ovulation. The findings suggest that the parts of the neuroendocrine system that are integral in
controlling sexual maturation are dependent upon the perception of light to function normally (Flynn-Evans et al., 2009).

Type-1 diabetes

Type-1 diabetes can also disrupt reproductive function by delaying menarche (Danielson, Palta, Allen, & D’Alessio, 2005). Hyperglycemia that results from poorly controlled diabetes can interfere with the endocrine system and cause a delay in menarche (Codner, Merino, & Tena-Sempere, 2012).

**Obesity, Diet, and Exercise**

Besides the aforementioned diseases that can affect sexual maturation, largely preventable conditions like obesity can also affect the onset of puberty. The growing concern of the obesity epidemic has not been without its effects upon children. In addition to the increased risks of developing diseases such as type-2 diabetes and hypertension, there is evidence that obesity triggers an earlier physical development in young children, and can influence an early onset of puberty and menarche in girls (Mumby et al., 2011).

It has been suggested that diet, even more than body weight, can influence the onset of menarche through the
alteration of hormone levels. The evidence is so strong that some researchers see diet as an etiological factor in both the immediate and long-term control of menarche (Sancheza, Kissinger, & Phillips, 1981).

A 2010 study compared the effect of animal protein intake with plant protein intake, looking at how both affect the onset of menarche in females. A high intake of animal protein during childhood (5-6 years) was associated with an earlier onset of menarche, while a high intake of vegetable protein during childhood was associated with a later onset of menarche. Also, those females in the highest tertile of animal intake had an onset of menarche that was 0.6 years earlier than those in the lowest tertile. It is suggested that one possible reason for this observation is that a high intake of animal protein during childhood can lead to obesity, which in turn can cause premature development. The results from this study indicate that a diet high in animal protein, particularly during early childhood, may have long-term effects on a girl’s physical development. A diet high in animal protein during childhood may be a contributing factor in an earlier onset of menarche (Gunther, Karaolis-Danckert, Kroke, Remer, & Buyken, 2010).
Data from a Loma Linda study have also shown that a meat-based diet is associated with an earlier onset of menarche. The results of this study showed that the age of menarche was an average of 6 months earlier for girls who ate meat than for vegetarian girls (Kissinger & Sanchez, 1987). It is hypothesized that a vegetarian diet may even reverse the declining trend towards early menarche in well-nourished females (Kissinger & Sanchez, 1987).

In addition to diet, exercise can be beneficial in the normalization of the neuroendocrine system, which can allow for a normal physical development. One study showed that girls who participated leisurely in activities such as dance, gymnastics, or swimming had a lower risk of attaining early menarche than those girls who did not participate in leisure activities (Moisan, Meyer, & Gingras, 1991). A similar study found that girls who played sports began menstruating later (15.7 years) than those who didn’t (13.3 years). Exercise may produce pressure on the reproductive system through its strenuous work, which can inhibit certain hormones that are responsible for sexual maturation (Satwanti, Bhalla, Kapoor, & Singh, 1983).
Concerns Associated With Early Menarche

It was previously shown that the timing of puberty and the onset of menarche are multifactorial. Physical and environmental factors, along with family influences, health, and nutrition can all affect how early or late menarche is attained. All factors that disrupt the endocrine system, whether to delay or accelerate the onset of menarche, are of concern.

Although there are risk factors to be considered with a relatively late attainment of menarche, the main focus of this discussion will center around the concerns associated with early menarche, since this is the trend that has been observed, particularly in more developed countries like the United States. Late menarche does come with its disease risks, however, such as increased risk for osteoporosis, infertility, and ovarian cancer (Danielson et al., 2005; Jordan, Webb, & Green, 2005). These risk factors are of particular importance to professional female athletes and females with certain inherited disorders as was previously discussed. For society in general, however, early menarche is more meaningful. Multiple concerns exist with the attainment of early menarche, such as increased risk of diseases and a potentially negative effect on society as a
whole. If the trend towards early menarche continues, it is possible that a number of diseases may be more frequently observed as well.

Impact on Society

Kathleen O’Grady of the Canadian Women’s Health Network describes the trend toward earlier menarche as resulting in the “loss of childhood” among young girls (O'Grady, 2008). Even though an 8-year-old girl who attains menarche is still an 8-year-old intellectually, physically she is not. Entrance into puberty comes with the added pressure from society for such a young girl to mature at an early age (O'Grady, 2008). The onset of puberty tends to increase adolescent exposure to substances like drugs and alcohol. Particularly if a female has entered puberty at an early age, she is more likely to lack the psychological maturity to handle her exposure to these substances, and may become more easily influenced to participate in substance abuse. It is now well established that early pubertal development, including an early onset of menarche, is a risk factor for engaging in risky behaviors, such as substance abuse (Tanner-Smith, 2012).
With early menarche also comes earlier sexual maturation. Apprehension is likely to be experienced by any parent who discovers that their young girl is developing rather quickly; with this discovery also comes the potential to become pregnant sooner. Although a young girl matures physically, she is most likely not prepared for the emotional, physical, and financial consequences associated with engaging in sexual activity. Early pubertal development is a risk factor for becoming sexually active sooner, and for becoming pregnant earlier in life, according to the American Academy of Pediatrics (American Academy of Pediatrics, 2007). A comparative study between White and Black girls showed that White girls who experience early menarche become pregnant at earlier ages than their peers. Also, Black and Hispanic girls tend to be more fertile when they engage in sexual activity at early ages, and are more likely than White girls to become pregnant when engaging in similar high-risk sexual behaviors (Dunbar, Sheeder, Lezotte, Dabelea, & Stevens-Simon, 2008). Young sexually active girls are less likely to be educated about the correct use of contraceptive methods and may be in denial about the possibility of becoming pregnant (American Academy of Pediatrics, 2007).
Girls who become sexually active at younger ages are also more likely to contract sexually transmitted infections (American Academy of Pediatrics, 2007). Younger people are more likely to use the withdrawal method during intercourse, which has a high failure rate and does not protect against sexually transmitted diseases and infections.

There is also an increased likelihood of coercion to be involved in a girl’s first sexual encounter if she is young at the time of coitarche. In a New Zealand study, 30% of women reported being coerced when they engaged in intercourse for the first time. The risk of coercion increased with younger ages of first encounter. Additionally, as the girls got older, they were more likely to regret their first experience. Most of the women (70%) who had intercourse before the age of 16 wished that they had waited longer to do so (Dickson, Paul, Herbison, & Silva, 1998).

Early pregnancies are a public health concern because of the increased burden on society that they produce. As of 2004, approximately 41.9% of all pregnancies were attributed to teenagers ages 15-19 (American Academy of Pediatrics, 2007). Teenage mothers are less likely to
finish high school and will subsequently remain less educated (American Academy of Pediatrics, 2007).

Disease Risks

Breast Cancer

Breast cancer risk in women increases with an earlier age at menarche. A case-control study of 1836 breast cancer patients examined commonalities among the women. Along with reporting late menopause, early menarche was common among all of the patients, and was found to be a risk factor for developing breast cancer (Paffenbarger, Kampert, & Chang, 1980). Another study demonstrated a 10% reduction in breast cancer risk for every 2-year delay in the onset of menarche among girls (Hsieh, Trichopoulos, Katsouyanni, & Yuasa, 1990). The possible explanation of this involves higher serum estrogen levels among women who experience early menarche, since this also indicates an earlier onset of ovulatory cycles. Additionally, these women tend to have lower testosterone and dehydroepiandrosterone levels, and a high estrogen-androgen ratio is considered a critical factor in determining breast cancer risk, along with high estrogen levels (Apter & Vihko, 1983). One study demonstrated that women who attained menarche at earlier
ages had estradiol levels that increased more rapidly at the beginning of their menstrual cycles than other women, which put them at risk for breast cancer for more days than others (Apter, Reinilä, & Vihko, 1989). These women were likely to experience excess estradiol stimulation at least until the age of 30 (Apter et al., 1989).

**Ovarian and Endometrial Cancer**

The risk of developing ovarian cancer is also increased with a decreasing age of menarche. Total ovulatory years were shown in one study to increase the risk of ovarian cancer, which included early menarche and late menopause (Franceschi, Vecchia, Helmrich, Mangioni, & Tognoni, 1982). Another study yielded similar results, demonstrating that late menarche and early menopause were associated with a decreased risk for ovarian cancer (Chiaffarino et al., 2001).

Endometrial cancer, or cancer of the lining of the uterus, was also found to be associated with an early onset of menarche in one study. Women with early menarche were 1.6 times more likely than other women to develop endometrial cancer (Elwood, Cole, Rothman, & Kaplan, 1977).
Diabetes and Cardiovascular Disease

According to the American Diabetic Association, an early age at menarche increases diabetes risk and increased body fat risk in older adults (Chen et al., 2011). A study done on 101,415 women also demonstrated that an onset of menarche before age 11 presented the highest risk factor for type-2 diabetes in adult women. This finding was also connected to an observation of excess body fat in the women (He et al., 2010). Early menarche is often accompanied by excess body fat, which can translate into adulthood to increase the risk of developing type-2 diabetes (Frontini, Srinivasan, & Berenson, 2003). Another study examining females 8-21 years old found that girls who attained menarche at earlier ages had harmful changes in insulin, blood glucose levels, and blood pressure than other girls.

Cardiovascular disease is also a concern for women who attain early menarche. It has been shown that precursors to cardiovascular disease can be determined as early as in childhood (Frontini et al., 2003). A prospective study done on over 15,000 women demonstrated that women who experienced early menarche were more likely to develop hypertension, incident cardiovascular disease, and coronary heart disease than other women. The study also found that
these women were at higher risks for cardiovascular disease mortality and all-cause mortality (Lakshman et al., 2009).

**Psychopathological Disorders**

Girls who attain menarche at earlier ages are more likely than their peers to experience psychopathological disorders. Chinese high-school students who reported earlier ages at menarche were more likely in one study to exhibit suicidal behaviors, anxiety, depression, and self-harming behaviors than their peers (Deng et al., 2002). In an Australian study, age at menarche was the strongest predictor of a girl’s risk to develop anxiety disorders or depression (Patton et al., 1996).

The documented research has shown that early menarche is associated with a higher risk for developing numerous diseases. As estrogen levels increase, a female is at higher risk for developing breast, ovarian, and endometrial cancers. With the added body fat that usually accompanies menarche, women who experience this earlier than normal are more likely than other women to develop diabetes and cardiovascular disease during adulthood. Females who attain menarche earlier also experience an increased risk for psychopathological conditions.
Body Mass Index

In this study, the effect of Body Mass Index on the age at menarche in young women was examined, and this factor will now be discussed in detail.

Body Mass Index is a measurement of a person’s body mass relative to their weight, and is calculated by dividing weight in kilograms by the square of the height (kg/m²) (CDC, 2011a). The number calculated is a measure of body fatness. It allows for the placement of various weights into categories that might lead to potential health problems (CDC, 2011a).

For adults, a BMI value that is less than 18.5 is considered to be underweight. A BMI between 18.5 and 24.9 is normal, between 25.0 and 29.9 is overweight, and 30.0 and above is considered to be overweight (CDC, 2011a). The body mass index scale, as used to measure obesity in adults, is not effective in measuring obesity in children because of their continued growth and development. As seen in Figure 2, the BMI percentile is used to assess a child’s size and growth patterns relative to other children in their age and sex group (CDC, 2011b). A child between 2 and 20 years old is considered underweight if he/she is in the 5th percentile for body weight and at a healthy weight
between the 5th and 85th percentile. Above the 85th percentile is considered overweight and equal to or greater than the 95th percentile is considered to be obese (CDC, 2011b). The percentage of obese children has doubled over the past decade, and has tripled for adolescents (American Academy of Pediatrics, 2013).

![Body Mass Index for girls ages 2-20](http://www.emedicinehealth.com/script/main/art.asp?articlekey=138368&ref=134567)

**Figure 2.** Body Mass Index for girls ages 2-20. Normal weight range is between the 5th and 85th percentile. Over 95% is considered to be obese. Adapted from Emedicinehealth (2008). Available online: http://www.emedicinehealth.com/script/main/art.asp?articlekey=138368&ref=134567
Obesity

Obesity is now considered to be a global pandemic (Komlos & Brabec, 2010). A recent CNN article reported "obesity is now a bigger health crisis globally than hunger" (Dellorto, 2012). According to the report, every country in the world, except for those in sub-Saharan Africa, is facing the growing problem of obesity at an alarming rate. Over the past 20 years, obesity has increased by 82% globally (Dellorto, 2012). In the United States alone, the average BMI of an 18-year-old White male has increased from just under 20 to more than 24.0 kg/m² (Komlos & Brabec, 2010).

Although genetics does play a role in the rising rates of obesity, it is clear that a shift in environment has had one of the greatest contributions to the observed trend. The Westernization of society has done more to contribute to this problem than any other factor, according to an economy report. This Westernization includes major labor-saving technologies of the 20th century, the introduction of television and radio broadcasting, the introduction of women in the workforce, and the spread of the fast-food culture (Komlos & Brabec, 2010). All of these contributions have led to less physical activity incorporated in the
daily life of Americans and a shift towards more calorie-
dense foods and a less nutritious diet.

These changes have not been without their effects upon
children. Obesity in children is also increasing in the
United States, as well as worldwide (Chou & Grossman,
2005). Children are engaging in more sedentary behavior,
spending less time in physical activity and more time
watching television and playing video games. The Third
National Health and Nutrition Examination survey found that
67% of children watched television at least 2 hours per day
and only 20% of children ages 8-16 had at least 2 bouts of
physical activity per week (Chou & Grossman, 2005). In
addition to this sedentary life, fast-food companies are
targeting children in commercial advertisements, leading to
a consumption of more calorie-dense foods (Chou & Grossman,
2005). Thus, the problem of obesity in children is
escalating as well, and obese children are more likely to
become obese adults (Cole, Bellizzi, Flegal, & Dietz,
2000).

For both children and adults, obesity comes with
health consequences. Higher BMI values in adults and BMI
percentile values in children are associated with increased
risks of diseases like diabetes, hypertension, cardiovascular disease, and certain cancers (Hoffman Center Staff, 2013). For example, of all the people diagnosed with diabetes, 80-90% are also diagnosed as being obese (Diabetic Care Services, 2013). Additionally, an increase in estrogen is also a risk factor for certain cancers, and adipose tissue is a common site of estrogen synthesis in women. Therefore, scientists link high BMI values with a higher risk of reproductive cancers in women (Hoffman Center Staff, 2013). It is estimated that the non-communicable diseases that continue to result from obesity will cost society over $30 trillion in the next 20 years (Komlos & Brabec, 2010).

BMI and Menarche

In addition to the many disease risks that are increased with an increasing BMI, evidence suggests that a high BMI percentile value may also place children at risk for attaining menarche at earlier ages than normal. The general trend toward early menarche and some of the concerns associated with it were previously noted. Yet with the general trend also shifting towards obesity in both
children and adults, it is meaningful to consider the association between these two factors.

In order for menstruation to commence in an adolescent girl’s life, 17% body fat is required, and 22% is required to sustain menstruation (Neinstein, 2013). In 1971, Frishe and Revelle first proposed the “critical body weight hypothesis” which suggested that the timing at which a female enters the reproductive phase is also triggered at a fixed level of body weight (Frische & Revelle, 1971). They hypothesized that when a female reaches the critical range weight, her metabolism increases, which in turn causes maturation of the ovaries and uterus, leading to the onset of menarche (Frische & Revelle, 1971). It is now generally accepted that fertility is influenced by body weight. A woman with a BMI under 19, for example, can experience difficulty conceiving (BBC News, 2002), and weight loss in obese women can improve their fertility (Clark et al., 1998). If, however, the hypothesis of Frishe and Revelle is true, then the fulfillment of this critical body weight range in a female (regardless of how old or young she is) could potentially trigger menarche either sooner or later than expected.
Indeed, in the years following Frische and Revelle’s (1971) observation, numerous studies have consistently found a link between higher BMI and early menarche in young girls. In the National Institute of Child Health and Development Study, 354 girls were assessed to determine the possible association between BMI and the age of puberty observed. The study found that from even an early age of 36 months, a high BMI z-score was associated with an early age of puberty. The rate of change in BMI before menarche was also significant. An acceleration of BMI was correlated with an earlier onset of puberty in the girls (Clark et al., 1998). A 2012 study on Korean girls also found that the BMI between ages 8 and 9 was associated with the age of menarche. It was also found that an increase in BMI between ages 7 and 8 was associated with earlier menarche in the girls (Oh et al., 2012). These results were consistent with the results from the National Institute of Child Health and Development study, showing that the rate at which BMI increased was also important. Another study published in the Journal of Obesity found that for every 1 kg/m² increase in childhood BMI, there was a 6.5% increase in risk of attaining early menarche (Mumby et al., 2011).
The problem of increased obesity may present more difficulties to society than was previously thought. Not only will children be at higher risk for the aforementioned diseases, but they may also be at risk for earlier physical development than normal, as seen in early menarche in females. This observation would then carry with it a host of other complications as was previously discussed.

**Summary of Chapter**

Puberty with the onset of menarche represents an important transition in the life of a female from childhood into adulthood. The physiological changes that accompany menarche allow for sexual maturity and the ability to become pregnant.

Over the past 100 years, there has been a declining trend toward earlier ages at menarche than what was once observed. Globally, these ages have been continually decreasing, and this trend has been observed in the United States as well.

Among the factors that are instrumental in contributing to the timing of menarche, physical factors such as race, genetics, and birth size play important
roles. Black girls tend to enter menarche earlier than both Hispanic and White girls, and Hispanic girls tend to enter menarche earlier than Whites. Several genes including leptin have been identified that also contribute to the timing of menarche. Females who are born with lower birth weights are also more likely to attain menarche sooner than girls who are born with normal weights. Environmental factors, such as the exposure to tobacco, PBB, and DDT, have all been shown to disrupt the function of the endocrine system, leading to a subsequent alteration in the timing of menarche.

Although both early menarche and late menarche are important to consider, there are greater risks for society in seeing the trend toward earlier menarche in females. With an early entrance into puberty comes an earlier introduction to environments that may not be appropriate for the immature mind, such as exposure to drugs, alcohol, and sex. This exposure might result in a loss of childhood, leading to earlier sexual encounters, earlier pregnancies, and lower levels of education for women.

Disease risks are also of concern. Breast, ovarian, and endometrial cancers are all risk factors for girls who attain menarche at earlier ages. These girls are also at
risk for diabetes, cardiovascular disease, and pathopsychological disorders.

The problem of obesity should also be considered in the discussion on early menarche. Both adults and children are becoming more overweight and obese. Along with other disease risks associated with high BMI, the attainment of early menarche is also significant. Numerous studies have demonstrated a link between high BMI and an accelerating BMI change in childhood with early menarche. BMI may not be a concern only for diseases like diabetes and coronary heart diseases; in contributing to an earlier attainment of menarche, it may also serve to further exacerbate the issues that are faced with early menarche.

In Chapter 3, the study undertaken to further observe the link between high BMI percentile values and early menarche in young girls will be described.
CHAPTER 3

METHODOLOGY

Introduction

This study was conducted in the context of a larger study that was done to assess the effect of soy consumption on physical development in adolescent girls and boys. Data were used to examine the association between BMI and the age of menarche in adolescent girls.

Recruitment

Participants were recruited mainly through direct contact in their schools. After gaining approval from the Institutional Review Board of both universities, permission was obtained from the schools’ principals and superintendents to conduct the survey.

Students were first introduced to the study through a general assembly, where they watched a promotional video about the study. Recruitment was done at the beginning of classes with the teachers’ consent. Students were informed
that the purpose of the study was to evaluate the effect of diet on physical development. They were told that they would receive a $10 iTunes card for completing an online survey and participating in a clinic, and that they would be entered in a drawing to win an iPad. Recruitment was also conducted during lunch periods, where sign-up sheets were available.

Participants were asked to complete an online parental consent form with their parents. Parents were then called and asked to verify the city of the child’s birth. Their verbal consent was also given to allow the child to participate in the study. A follow-up e-mail with log-in instructions was then sent to the child’s e-mail address as provided on the form. Some of the participants were given paper forms that included a signature of consent from the parent. These students, who did not use the online option, handed in the form on the following day.

**Assessment of Food Intake**

A detailed online questionnaire was used to collect data about food consumption and self-reported data about the age of menarche. The questionnaire also assessed the current stage of puberty.
There were questions in the survey regarding how often convenience foods, fruits and vegetables, and soy foods were consumed. Participants were also asked about the consumption of dairy foods, protein foods, snacks, and beverages. Particular interest was given to the consumption of soy foods, since the focus of the study was to examine soy consumption on physical development. For the statistical analysis, participants who identified themselves as never consuming foods containing meat were placed in the “Vegetarian” category; all other students were classified as “Omnivores.”

**Assessment of Physical Development**

In the physical development section, females were asked to recall the date of menarche using a visual timeline. They were then asked to identify the stage of puberty they were currently in using a visual representation of the Tanner Stages (stages 1-5), and to recall the age at which they began wearing a brassiere. Males were also asked to recall important dates in their physical development, such as when their voices began to change, when they had their first wet dream, and when they started growing pubic and axillary hair.
Recollection of these important dates was facilitated by the use of a timeline. The last series of questions asked the participants to identify their physical growth by recording their self-reported weight and height measurements.

**Clinics**

Clinics were conducted at each school after the participants completed the online survey. Heights were measured using a digital stadiometer; weight and body composition were both recorded using a portable TANITA scale; waist and hip circumferences were recorded with a non-stretchable tape measure. Height, weight, and waist and hip circumference measurements were taken thrice, and the average of each of these measurements was recorded for greater accuracy.

For BMI assessments, the raw measurement used for adults (kg/m²) could not be used. This measurement is not appropriate for children and adolescents under the age of 21 because they are still growing; adolescents are instead compared with other adolescents of the same sex and age. Using the computed BMI, along with the age and sex of the
participants, the raw BMI values were converted to BMI percentiles using an online conversion tool.

Data Analysis

The data were organized and compiled for analysis using the SPSS program. Values for all of the variables including school and school type, education level, ethnicity, and weight category were coded and entered into the system. The data were analyzed using linear regression, ANOVA, and \( t \) tests. Frequency tables, means, and standard deviations were also used to analyze and interpret the data.
CHAPTER 4

RESULTS

Introduction

This study was designed to evaluate the relationship between BMI and the age of menarche in adolescent girls. Participants filled out an online questionnaire that asked them questions about their physical development. They also participated in a clinic where height, weight, and body fat measurements were taken.

The data were organized and compiled for analysis using the SPSS program. Linear regression analysis was used to examine the correlations between BMI and the age of menarche, body fat percentage and the age of menarche, Tanner stages for pubic hair development and BMI, and Tanner stages for breast development and BMI. ANOVA was used to examine the variance between ethnicities based on the age of menarche. Comparison between the age of menarche in Seventh-day Adventist schools and public schools was analyzed using t tests. Comparison between the age of menarche and BMI percentile values based on vegetarian
status was also analyzed using t tests. Frequency tables, means, and standard deviations were also used to analyze and interpret the data.

**Participants**

There were a total of 304 participants in Grades 7-12 from 10 schools in California and Michigan. Most of the participants (n=218) were from Seventh-day Adventist schools, and 33 were from public schools. Only 22% of participants were classified as vegetarians, while 77% were classified as omnivores. The participants ranged in age from 12-19 years, with an average age of 15.4 years. The majority of the females were White (35.2%), but there were also Black, Asian, and Hispanic participants.

**Variables Description**

**BMI Percentile**

BMI percentile values placed the females in underweight, normal weight, overweight, and obese categories, relative to the expectations based on sex and age. The average BMI percentile was 56.1 (SD=27.3) (see Table 1).
Body Fat Percentage

The body fat percentage measurements were used to analyze the amount of body fat each participant had, relative to the amount of fat-free mass. The average percentage of body fat of the participants \((n=113)\) was 26.2\% \((SD=7.8)\) (see Table 1).

Age of Menarche

The age of menarche was used to determine if a participant was at a higher risk for certain diseases and societal obstacles, as outlined in Chapter 2. Table 1 also shows that the average age of menarche, as reported by 251 participants, was 12.2 years \((SD=1.5)\).

Maternal Ethnicity

Since there was no access to the ethnicity of the participants, the ethnicity of the mother was recorded. This variable was used to determine the risk for early menarche (see Chapter 2). The participants were placed in five categories of ethnicity: White, Black, Asian, Hispanic, and Other. Most of the participants in the study were White females (35.2\%) (see Table 2).
Table 1

*Descriptive Statistics of the Sample*

<table>
<thead>
<tr>
<th>Description</th>
<th>n</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>304</td>
<td>15.4 (1.8)</td>
</tr>
<tr>
<td>BMI Percentile (%)</td>
<td>272</td>
<td>56.1 (27.3)</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>113</td>
<td>26.2 (7.8)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>113</td>
<td>161.6 (6.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>113</td>
<td>56.8 (13.3)</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>113</td>
<td>76.8 (11.4)</td>
</tr>
<tr>
<td>Hip (cm)</td>
<td>113</td>
<td>93.8 (12.0)</td>
</tr>
<tr>
<td>Age of menarche (days)</td>
<td>251</td>
<td>4,455.0 (556.0)</td>
</tr>
<tr>
<td>Age of menarche (years)</td>
<td>251</td>
<td>12.2 (1.5)</td>
</tr>
</tbody>
</table>

Table 2

*Distribution of Maternal Ethnicity*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>35.2 (107)</td>
</tr>
<tr>
<td>Black</td>
<td>16.4 (50)</td>
</tr>
<tr>
<td>Asian</td>
<td>15.8 (48)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>19.4 (59)</td>
</tr>
<tr>
<td>Other</td>
<td>5.6 (17)</td>
</tr>
</tbody>
</table>

*Note.* There were 23 non-responders, and the data were adjusted for responders.
Tanner Stages

Tanner stages for breast development and pubic hair development were recorded to assess the physical development in these two categories, compared with other females. Most of the females (32.6%) reported being in stage 4 for breast development and stage 4 for pubic hair development (37.5%) (see Tables 3 and 4).

Table 3

Stages of Breast Development of Participants (According to the Tanner Scale for Breast)

<table>
<thead>
<tr>
<th>Breast Tanner Stage</th>
<th>%  (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7 (2)</td>
</tr>
<tr>
<td>2</td>
<td>7.2 (22)</td>
</tr>
<tr>
<td>3</td>
<td>25.3 (77)</td>
</tr>
<tr>
<td>4</td>
<td>32.6 (99)</td>
</tr>
<tr>
<td>5</td>
<td>31.6 (96)</td>
</tr>
</tbody>
</table>

Note. There were 8 non-responders, and the data were adjusted for responders.

Vegetarian Status

There is evidence that a vegetarian diet may protect females from attaining menarche too early, and can also result in lower BMI values (see Chapter 2). Therefore, this variable was also included. Most of our participants were classified as omnivores (77.3%), as seen in Table 5.
Table 4

Stages of Pubic Hair Development of Participants
(According to the Tanner Scale for Pubic Hair)

<table>
<thead>
<tr>
<th>Pubic Tanner Stage</th>
<th>%</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.0</td>
<td>(9)</td>
</tr>
<tr>
<td>2</td>
<td>11.2</td>
<td>(34)</td>
</tr>
<tr>
<td>3</td>
<td>25.0</td>
<td>(76)</td>
</tr>
<tr>
<td>4</td>
<td>37.5</td>
<td>(114)</td>
</tr>
<tr>
<td>5</td>
<td>20.7</td>
<td>(63)</td>
</tr>
</tbody>
</table>

Note. There were 8 non-responders, and the data were adjusted for responders.

Table 5

Distribution of Participants by Vegetarian Status

<table>
<thead>
<tr>
<th>Status</th>
<th>%</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetarian</td>
<td>22.0</td>
<td>(67)</td>
</tr>
<tr>
<td>Omnivore</td>
<td>77.3</td>
<td>(235)</td>
</tr>
</tbody>
</table>

Other Descriptive Statistics

Table 6 shows the distribution of participants according to grade level. Grade levels were almost evenly distributed, ranging from 14.5% to 17.8% in each grade.
Table 6

Distribution of Participants by Grade Level

<table>
<thead>
<tr>
<th>Grade</th>
<th>%</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>14.5</td>
<td>(44)</td>
</tr>
<tr>
<td>8</td>
<td>17.4</td>
<td>(53)</td>
</tr>
<tr>
<td>9</td>
<td>17.8</td>
<td>(54)</td>
</tr>
<tr>
<td>10</td>
<td>17.8</td>
<td>(54)</td>
</tr>
<tr>
<td>11</td>
<td>17.8</td>
<td>(54)</td>
</tr>
<tr>
<td>12</td>
<td>14.8</td>
<td>(45)</td>
</tr>
</tbody>
</table>

Table 7 describes the distribution of participants by participating schools, both in California and Michigan. Of all the participants, 58.6% came from California and 41.4% from Michigan, including 3.0% who were home-schooled.

Table 8 describes the distribution of participants by school type. Almost 90% of our participants were from Seventh-day Adventist schools.

Table 9 shows the distribution of BMI categories among the participants using the self-reported heights and weights. Most of the participants (71.4%) were in the normal weight category, while only 14.4% were either in the overweight or obese category.
Table 7

**Distribution of Participants by Participating Schools**

<table>
<thead>
<tr>
<th>School</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesa Grande Academy</td>
<td>7.9 (24)</td>
</tr>
<tr>
<td>Loma Linda Academy</td>
<td>22.7 (69)</td>
</tr>
<tr>
<td>La Sierra Academy</td>
<td>18.8 (57)</td>
</tr>
<tr>
<td>Redlands Adventist Academy</td>
<td>9.2 (28)</td>
</tr>
<tr>
<td>Ruth Murdoch Elementary School</td>
<td>7.2 (22)</td>
</tr>
<tr>
<td>Andrews Academy</td>
<td>14.8 (45)</td>
</tr>
<tr>
<td>Berrien Springs High School</td>
<td>8.2 (25)</td>
</tr>
<tr>
<td>Berrien Springs Middle School</td>
<td>5.9 (18)</td>
</tr>
<tr>
<td>Home-Schooled</td>
<td>3.0 (9)</td>
</tr>
<tr>
<td>Niles Adventist School</td>
<td>2.3 (7)</td>
</tr>
</tbody>
</table>

Table 8

**Distribution of Participants by School Type**

<table>
<thead>
<tr>
<th>School type</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seventh-day Adventist</td>
<td>85.9 (261)</td>
</tr>
<tr>
<td>Public</td>
<td>14.1 (43)</td>
</tr>
</tbody>
</table>

Table 9

**Distribution of Participants by BMI Categories (Using Self-reported Height and Weight)**

<table>
<thead>
<tr>
<th>Category</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>3.6 (11)</td>
</tr>
<tr>
<td>Normal weight</td>
<td>71.4 (217)</td>
</tr>
<tr>
<td>Overweight</td>
<td>9.5 (29)</td>
</tr>
<tr>
<td>Obese</td>
<td>4.9 (15)</td>
</tr>
</tbody>
</table>

*Note. There were 32 non-responders, and the data were adjusted for responders.*
Table 10 shows the distribution of the highest education level achieved by the mother. Most of the mothers had attained a college degree (75.3%).

Table 10

Education Level of the Mother of the Participants (Highest Level Achieved)

<table>
<thead>
<tr>
<th>Education level</th>
<th>%</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary</td>
<td>0.7</td>
<td>(2)</td>
</tr>
<tr>
<td>High School</td>
<td>12.8</td>
<td>(39)</td>
</tr>
<tr>
<td>Vocational</td>
<td>3.6</td>
<td>(11)</td>
</tr>
<tr>
<td>Bachelor’s</td>
<td>38.5</td>
<td>(117)</td>
</tr>
<tr>
<td>Master’s</td>
<td>27.6</td>
<td>(84)</td>
</tr>
<tr>
<td>Doctoral</td>
<td>9.2</td>
<td>(28)</td>
</tr>
</tbody>
</table>

Note. There were 23 non-responders, and the data were adjusted for responders.

Association of Selected Variables

BMI by School Type

The comparison of BMI percentile values between Seventh-day Adventist schools and public schools was examined to assess the difference in general health risks in both groups. In this study, 15% of participants in Seventh-day Adventist schools fell into either the overweight or obese category; similarly, 11.6% of public school participants were either overweight or obese. The
proportion of students that fell into these categories from both schools was similar (see Table 11).

Table 11
Distribution of BMI Category by School Type

<table>
<thead>
<tr>
<th>BMI Category</th>
<th>%</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seventh-day Adventist</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>3.8</td>
<td>10</td>
</tr>
<tr>
<td>Normal</td>
<td>72.4</td>
<td>189</td>
</tr>
<tr>
<td>Overweight</td>
<td>9.6</td>
<td>25</td>
</tr>
<tr>
<td>Obese</td>
<td>5.4</td>
<td>14</td>
</tr>
<tr>
<td><strong>Public School</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>2.3</td>
<td>1</td>
</tr>
<tr>
<td>Normal</td>
<td>65.1</td>
<td>28</td>
</tr>
<tr>
<td>Overweight</td>
<td>9.3</td>
<td>4</td>
</tr>
<tr>
<td>Obese</td>
<td>2.3</td>
<td>1</td>
</tr>
</tbody>
</table>

Vegetarian Status by School Type

In addition to a healthy lifestyle, Seventh-day Adventists also promote a vegetarian diet. In the Seventh-day Adventist schools, 24.9% of the participants were vegetarians; in the public schools, only 4.7% were vegetarians (see Table 12).
Table 12

*Distribution of Vegetarian Status by School Type*

<table>
<thead>
<tr>
<th>Vegetarian Status</th>
<th>%</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seventh-day Adventist</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetarian</td>
<td>24.9</td>
<td>65</td>
</tr>
<tr>
<td>Omnivore</td>
<td>75.1</td>
<td>196</td>
</tr>
<tr>
<td><strong>Public School</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetarian</td>
<td>4.7</td>
<td>2</td>
</tr>
<tr>
<td>Omnivore</td>
<td>90.7</td>
<td>39</td>
</tr>
</tbody>
</table>

Age of Menarche by Ethnicity

The age at menarche can be influenced by ethnicity (see Chapter 2). This study, however, found no relationship between the two variables (see Table 13). There was also no difference in the age of menarche between Whites and non-Whites.

Age of Menarche by School Type

The age of menarche in Seventh-day Adventist schools and public schools was also compared. Participants in Seventh-day Adventist schools attained menarche an average of 50 days earlier than participants from public schools (see Table 14).
Table 13

*Age of Menarche in Days Based on the Ethnicity of the Mother of the Participants (n=242)*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>%  (n)</th>
<th>Mean days (SD)</th>
<th>Mean years</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>35.2 (107)</td>
<td>4,527.0 (572.0)</td>
<td>12.4</td>
</tr>
<tr>
<td>Black</td>
<td>16.4 (50)</td>
<td>4,412.0 (536.0)</td>
<td>12.1</td>
</tr>
<tr>
<td>Asian</td>
<td>15.8 (48)</td>
<td>4,387.0 (568.0)</td>
<td>12.0</td>
</tr>
<tr>
<td>Hispanic</td>
<td>19.4 (59)</td>
<td>4,420.0 (538.0)</td>
<td>12.1</td>
</tr>
<tr>
<td>Other</td>
<td>5.6 (17)</td>
<td>4,458.0 (661.0)</td>
<td>12.2</td>
</tr>
</tbody>
</table>

*Note: SD=standard deviation; for comparison among all groups, p=0.639*

Table 14

*Distribution of Age of Menarche by School Type*

<table>
<thead>
<tr>
<th>School Type</th>
<th>n</th>
<th>Mean (days)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seventh-day Adventist</td>
<td>218</td>
<td>4,449</td>
<td>573</td>
</tr>
<tr>
<td>Public school</td>
<td>33</td>
<td>4,491</td>
<td>433</td>
</tr>
</tbody>
</table>

*Note. SDA=Seventh-day Adventist; SD=standard deviation; for comparison between both groups, p=0.098*

BMI Percentiles and Vegetarian Status

The difference in BMI values of vegetarians and omnivores was also examined. The average BMI percentile
value for vegetarians (50.5±24.8) was lower than the average value for omnivores (59.3±27.2) (see Table 15).

Table 15

<table>
<thead>
<tr>
<th>Vegetarian status</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetarian</td>
<td>56</td>
<td>50.5</td>
<td>24.8</td>
</tr>
<tr>
<td>Omnivore</td>
<td>186</td>
<td>59.3</td>
<td>27.2</td>
</tr>
</tbody>
</table>

Note. SD=standard deviation; for comparison between both groups, p=0.074.

Age of Menarche by Vegetarian Status

Vegetarians and omnivores were compared to see if there was a difference in the age of menarche between the two groups. Vegetarians did attain menarche an average of 56.7 days later than omnivores (see Table 16).

Table 16

<table>
<thead>
<tr>
<th>Vegetarian status</th>
<th>n</th>
<th>Mean days (SD)</th>
<th>Mean years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetarian</td>
<td>56</td>
<td>4,500.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Omnivore</td>
<td>186</td>
<td>4,443.0</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Note. SD=standard deviation; adjustments were made for BMI percentile; for comparison between both groups, p=0.729.
Other Associations

Table 17 shows the correlation between the Tanner stages of development for breast and pubic hair with vegetarian status. Marginal significance was observed in the correlation between the Tanner stage for pubic hair development and vegetarian status ($p=0.053$).

Table 17

<table>
<thead>
<tr>
<th>Vegetarian Status</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast Tanner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetarian</td>
<td>3.94</td>
<td>0.87</td>
</tr>
<tr>
<td>Omnivore</td>
<td>3.88</td>
<td>1.00</td>
</tr>
<tr>
<td>Public Tanner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetarian</td>
<td>3.85</td>
<td>0.89</td>
</tr>
<tr>
<td>Omnivore</td>
<td>3.57</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Note. For comparison of breast between both groups, $p=0.665$; for comparison of pubic hair between both groups, $p=0.053$.

Table 18 illustrates the correlation between body fat measurements (BMI measurements and body fat percentage) and the age of menarche.
Table 18

Correlation of Body Fat Measurements With Menarche

<table>
<thead>
<tr>
<th>Measurement</th>
<th>n</th>
<th>Mean</th>
<th>$B$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI percentile</td>
<td>272</td>
<td>56.1</td>
<td>-0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>% body fat</td>
<td>113</td>
<td>26.2</td>
<td>-1.00</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Note. $\beta$=adjusted correlation coefficient.

Table 19 shows the correlation between the Tanner stages of development for breast and pubic hair with BMI percentile values. There was a significant positive correlation between the Tanner stage for breast development and BMI percentile ($p < 0.05$).

Table 19

Correlation of Tanner Stages With BMI Percentile

<table>
<thead>
<tr>
<th>Tanner measurement</th>
<th>Mean ($SD$)</th>
<th>$r$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>3.93 (0.96)</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td>Pubic Hair</td>
<td>3.65 (1.04)</td>
<td>0.08</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note. SD=standard deviation; $r$=Pearson’s correlation coefficient; mean BMI percentile= 56.19.

Table 20 shows the correlation between the Tanner stages of development for breast and pubic hair with percent body fat. There was a significant positive
correlation between both breast and pubic hair development and percent body fat ($p<0.05$).

Table 20

<table>
<thead>
<tr>
<th>Tanner measurement</th>
<th>Mean (SD)</th>
<th>$r$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>3.93 (0.96)</td>
<td>0.37</td>
<td>0.00</td>
</tr>
<tr>
<td>Pubic Hair</td>
<td>3.65 (1.04)</td>
<td>0.19</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Note. SD = standard deviation; $r$ = Pearson’s correlation coefficient; mean body fat percentage = 26.2%.

**Hypothesis Testing**

**BMI Percentiles and Age of Menarche**

Research Hypothesis 1: There is a negative correlation between BMI percentile and the age of menarche; adolescent girls who have higher BMI values will experience menarche at earlier ages than girls with lower BMI values.

When adjusting for vegetarian status, a negative correlation was observed between the BMI percentiles of the girls and the age of menarche attained ($\beta=-0.146; p=0.024$). Girls who fell into higher BMI percentile categories attained menarche at earlier ages than girls who fell into lower BMI percentile categories. For every percentile
increase in BMI values, the age of menarche was attained an average of 3 days earlier.

Body Fat and Age of Menarche

Research Hypothesis 2: There is a significant correlation between the age of menarche in adolescent girls and percent body fat percentage values.

The correlation between body fat and the age of menarche was tested using multiple linear regression, while adjusting for the mother’s education level. No significant correlation was observed between the age of menarche and body fat percentage measurements ($\beta=-0.098; p=0.360$).

Age of Menarche and Ethnicity of the Mother

Research Hypothesis 3: There is a significant difference in the age of menarche among adolescent girls of different ethnicities.

When ANOVA was used to analyze the age of menarche based on the mother’s ethnicity, no significant difference was found ($F_{4, 237}=0.633, p=0.639$). Results demonstrated that ethnicity was not a significant contributor to the age of menarche observed in the participants, although among Whites, Blacks, and Hispanics, the mean ages of menarche
were consistent with previous research. Blacks attained menarche 115 days earlier than Whites on average.

An additional analysis was also done to compare the age of menarche between Whites and non-Whites. The result for this was also insignificant (two-sample $t$ (95) = -1.174, $p=0.244$).

Vegetarian Status and Age of Menarche

Research Hypothesis 4: There is a significant correlation between the age of menarche and vegetarian status.

No significant correlation was found between vegetarian status and the age of menarche. Although the vegetarians did attain menarche an average of 2 months before the omnivores, the results were not significant. However, in this study, the vegetarians were more developed in both breast and pubic hair than the omnivores. A slight significance was observed between pubic hair development and vegetarian status ($p=0.053$). It should also be noted that the average age of vegetarians (15.6) was similar to the average age of omnivores (15.4).
Self-reported and Actual Measurements

In assessing the validity of self-reported height and weight measurements, a strong correlation existed between the self-reported measurements and the actual measurements taken at the clinics (for height, \( r=0.951 \); for weight, \( r=0.864 \)). Therefore, it can be assumed that the self-reported height and weight measurements used to calculate the BMI percentiles for some of the participants were as reliable as the results obtained from those participants who were measured at the clinics.
CHAPTER 5

SUMMARY, DISCUSSION, AND CONCLUSION

Summary

The purpose of this study was to evaluate if BMI percentile values in adolescent girls were associated with the age of menarche. The study design was a clinic-based and questionnaire-based cross-sectional descriptive study. Data from participants’ age, height and weight measurements, waist and hip measurements, body fat percentage measurements, and age at menarche were collected through online questionnaires and clinics.

Discussion

The average age of menarche in this study was 12.2 years (+1.5), which is similar to the average age of 12.5 years reported in the United States (Anderson et al., 2003).

Oh et al. (2012) found that Korean girls who attained menarche before age 12 were taller and heavier than girls who did not (Oh et al., 2012). It was also discovered that
the girls with early menarche had higher BMI values and higher body fat measurements (Oh et al., 2012). The findings of this study were consistent with previous research in showing a relationship between BMI and the age of menarche. In this study, it was discovered that girls who had higher BMI percentile values reported earlier ages at menarche than girls with lower BMI percentile values ($p=0.024$). It was also observed that for every BMI percentile increase, menarche was attained an average of 3 days earlier ($r=-0.146$). These results show a negative correlation between BMI percentile values and menarche.

There was also a significant correlation between the Tanner stages for both breast and pubic hair development and BMI percentile values.

The results showing the association between body fat percentage and the age of menarche were not consistent with the aforementioned research. The average body fat measurement of the girls was 27.6% ($\pm 8.8$), and ranged from 11.6% to 52.9%. There was no correlation between percentage of body fat measurements and the age of menarche in the participants. However, there was a significant positive correlation between percentage of body fat measurements and
the Tanner stages of both breast and pubic hair
development.

Entrance into menarche requires at least 17% body fat
(Neinstein, 2013). Since there was such a wide range of
measurements, it was expected that girls with higher
measurements would report earlier ages at menarche, with
the assumption that they had attained 17% body fat earlier
in life. Yet, this was not the case. Even though a 17% body
fat measurement is required for the onset of menarche, it
may be that the attainment of this body fat measurement
does not automatically trigger the onset of menarche.
Indeed, menarche is triggered by complex interactions of
the endocrine system (Windham et al., 2004). Even though
obesity is an endocrine system disrupter, other factors may
influence the age of menarche. The result of this would be
that a female could attain menarche at a later age than
expected, even though she may have higher body fat
measurements.

It should be considered that since the recollection of
the age of menarche was retrospective, the correlation
between body fat percentage and the age of menarche may not
have been precise. For adolescent girls, body fat
measurements generally increase with age, due to the
development of breasts, hips, and thighs. Therefore, if a participant’s body fat was measured at a later stage of development, higher measurements would not necessarily correlate with an earlier age at menarche, depending on which happened first. This could offer a possible explanation for the highly significant correlation seen between body fat percentage and Tanner measurements. A female who is more developed, being in higher stages of pubic hair and breast development, would have higher percentage of body fat measurements. The correlation would not necessarily mean that higher body fat measurements were implicated in the onset of earlier menarche.

The possibility also exists that the alteration of body fat measurements due to growth spurt of some of the females may have affected the results. In other words, a female could have had a high percentage of body fat measurement at the time of menarche, but then experienced a growth spurt afterwards, which could lower the body fat measurement. If that female participated in the study after the growth spurt with a more normal body fat measurement, it would be difficult to determine that an earlier age of menarche was associated with a high body fat measurement. Therefore, even though measuring body fat percentage
provides added information about body composition, the correlation between BMI percentile and menarche offers more dependable results in this study, since the measurements take age into account.

Maternal ethnicity was not associated with the age of menarche. Several studies discovered that Black girls attain menarche 3 months earlier than White girls on average, and that they also begin menstruating before Hispanic girls (Chumlea et al., 2003; Freedman et al., 2002). Hispanic girls usually attain menarche earlier than White girls (Chumlea et al., 2003). Since there was no access to the ethnicity of the participants, the ethnicity of the mother was used, with the assumption that the child also shared that ethnicity. It is possible that some of the girls may not have shared the ethnicity of the mother, particularly if they were biracial or multiracial. The results showed that White girls did attain menarche later than both Hispanics and Blacks, and that Blacks attained menarche earlier than both Whites and Hispanics. However, the results were not significant, even when further dividing the groups into Whites and non-Whites.

Vegetarian status was also not significantly correlated with the age of menarche, even though
vegetarians attained menarche an average of 2 months later than omnivores. Interestingly, however, vegetarians were more developed in both breast and pubic hair development, as indicated by the Tanner stages. For pubic hair development, there was a slight significance ($p=0.053$). It may be that being vegetarian predisposes a young girl to faster physical development. It may also be that the small size of vegetarians ($n=56$) compared with omnivores ($n=186$) could have affected these results. Therefore, further study is recommended.

Strengths

One strength of this study was that the method used for recollection of the age of menarche was found to be reliable. Although a faulty memory of the participant is possible, the visual aids used in the online questionnaire are more reliable than other methods.

The instruments used to take measurements at the clinics (TANITA scale, stadiometer) were also reliable tools. Additionally, anthropometric measurements of the participants were taken thrice for accuracy. Even for those participants whose BMI percentile values were based on self-reported measurements, there was a strong correlation
between their measurements and measurements that were taken at the clinics.

**Weaknesses and Limitations**

One weakness of the study was that it was done in the context of a larger study focusing on how soy intake affects physical development. Therefore, there was limited access to data that would enhance the study. For example, the questionnaires were geared toward assessing food consumption. A more focused questionnaire for this study would have asked other questions geared toward assessing obesity patterns that the participant has experienced. Other questions about weight history and the mother’s age at menarche could have also been asked, which would have provided additional data for the study.

Another weakness involved the BMI and percentage of body fat measurements. For both BMI percentile and body fat measurements, the assumption was made that the participants’ measurements remained relatively constant from at least the time of menarche to the time of the study. Since this was a cross-sectional study, these measurements were taken only at the time of the study.
Although it is true that an obese child is more likely to remain obese through adolescence into adulthood, this is not always the case. The extent of obesity may also change. In reality, it is possible that BMI percentile and percentage of body fat measurements could change as the child is growing. Certainly, some of the participants who were older teenagers at the time of the study may have already experienced a growth spurt. Growth spurts are often accompanied by a balancing of height and weight, which may theoretically place some females in different BMI percentile categories and body fat measurements than before. Therefore, the BMI percentile categories and body fat measurements of these females at the time of the study may not have been the category they were in at their onset of menarche. In such cases, we were limited in determining the influence of BMI and body fat on menarche.

Another weakness of the study was that there was a very small sample size of obese or overweight females (n=44) compared with underweight and normal weight females (n=228). A larger sample size of overweight and obese participants may have affected the correlation observed.
Suggestions

This study on the relationship between BMI and menarche was done as a cross-sectional study. Perhaps the most meaningful suggestion for future consideration is to conduct this research as a longitudinal study. Oh et al. (2012) found that an accelerating BMI in childhood is correlated with an early age of menarche, particularly between the ages of 7 and 8. The BMI between ages 8 and 9 seems to also influence the age at menarche (Oh et al., 2012). A 10-year longitudinal study from ages 6-16 may be of great benefit. It would allow for examination of the changes in weight and other patterns during those critical years before the onset of menarche. For assessing changes in percentage of body fat, a longitudinal study would be of great value. Investigation could be done on the relationship between body fat measurements and the timing of menarche from an early age. Although longitudinal studies require more effort, for such a study, the results would be meaningful.

Conclusion

Despite its limitations, this study contributes to existing literature. It is consistent with other studies
that have demonstrated a negative correlation between BMI percentile values and the age of menarche. This study showed that higher BMI percentile values in girls are associated with an earlier age of menarche.
APPENDIX

SELECTED QUESTIONS FROM THE QUESTIONNAIRE FOR FEMALES
Physical Development

Please report your age (in years and to the nearest month) for each of the following events. Example: If your first period came 2 months after you turned 12, choose 12 for years and 2 for months. If it has not happened to you yet, choose "Has Not Happened Yet" and do not choose anything for Years or Months.

AGE WHEN YOU HAD YOUR FIRST PERIOD (AND AFTER WHICH YOU HAD YOUR PERIOD EVERY MONTH)
- [ ] years - [ ] months [ ] Has not happened yet

AGE WHEN YOU STARTED WEARING A BRA
- [ ] years - [ ] months [ ] Has not happened yet

AGE WHEN HAIR STARTED GROWING IN THE AREA AROUND YOUR VAGINA
- [ ] years - [ ] months [ ] Has not happened yet
Physical Development

Look at the following drawings. Which of these drawings looks most like you now?

1. The breasts are flat.
2. The breasts form small mounds.
3. The breasts form larger mounds than in #2.
4. The nipple and the surrounding part (the areola) make up a mound that sticks up above the breast.
5. Only the nipple sticks out beyond the breast.

Look at the following drawings. Which of these drawings looks most like you now?

1. No hair.
2. Very little hair.
3. Quite a lot of hair.
4. The hair has not spread over the thighs.
5. The hair has spread over the thighs.
Physical Development Timeline

Drag the following development stages below onto the slot above the month(s) they occurred. There is no correct order. If they occurred before or after the ages shown here, drag them onto the before or after slots, respectively. If they have not yet occurred, drop them in the “Has Not Occurred” box.

Your birthday is on April 6, 1996.

[Diagram with development stages and timeline]
Physical Growth

For the items below you will need to take some measurements.

Please measure your weight, height, waist, and hip and fill in the boxes.

Note the measurement instructions as you hover over headings.

How did you make your measurements? Select [ ]
## Lifestyle

<table>
<thead>
<tr>
<th>Question</th>
<th>Select Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you eat breakfast?</td>
<td></td>
</tr>
<tr>
<td>What do you usually eat for lunch?</td>
<td></td>
</tr>
<tr>
<td>At what time do you usually eat dinner/supper?</td>
<td></td>
</tr>
<tr>
<td>Do you usually eat a snack or anything after dinner/supper?</td>
<td></td>
</tr>
<tr>
<td>What time do you usually go to sleep on the weekdays?</td>
<td></td>
</tr>
<tr>
<td>What time do you usually go to sleep on the weekends?</td>
<td></td>
</tr>
<tr>
<td>How often during the week do you usually get involved in a vigorous physical activity/exercise?</td>
<td></td>
</tr>
<tr>
<td>How much time do you usually spend in vigorous physical activity?</td>
<td></td>
</tr>
<tr>
<td>Have you tried to go on a diet?</td>
<td></td>
</tr>
<tr>
<td>On average, how many hours of sleep do you usually have?</td>
<td></td>
</tr>
<tr>
<td>Food Item</td>
<td>Portion</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Hamburger Sandwich</td>
<td>1 medium</td>
</tr>
<tr>
<td>Hotdog Sandwich</td>
<td>1 medium</td>
</tr>
<tr>
<td>Sandwiches</td>
<td>1 sandwich</td>
</tr>
<tr>
<td>Breakfast Sandwich/Burritos</td>
<td>1 medium</td>
</tr>
<tr>
<td>Burritos</td>
<td>1 medium</td>
</tr>
<tr>
<td>Tacos</td>
<td>1 medium</td>
</tr>
<tr>
<td>Quesadilla</td>
<td>1 medium</td>
</tr>
<tr>
<td>Pizza</td>
<td>1 medium slice</td>
</tr>
<tr>
<td>Egg/Spring Rolls</td>
<td>1 egg/spring roll</td>
</tr>
<tr>
<td>Sushi/Kimbap</td>
<td>4-6 pieces</td>
</tr>
<tr>
<td>Nachos</td>
<td>6-8 pieces</td>
</tr>
</tbody>
</table>
Instructions

- For more information, hover over the food name.
- Consider the portion size when making your selection.

**MIXED DISHES: PROTEIN WITH VEGETABLES**
1 cup

**MIXED DISHES: PROTEIN WITH PASTA/NOODLES**
1 cup

**MIXED DISHES: PROTEIN WITH RICE**
1 cup

**MIXED DISHES: PROTEIN WITH BEANS/LEGUMES**
1 cup

For the following protein foods, DO NOT include the ones you eat in mixed dishes or convenience foods.

**TOFU/TEMPEH**
1 piece the size of a deck of cards or ½ cup

**PATTIES**
1 medium patty

**CHICKEN**
1 medium piece or 4-6 nuggets

**STEAK/ROAST**
1 piece the size of a deck of cards

**MEATLOAF/METBALLS**
1 piece the size of a deck of cards or 4 meatballs

**LINKS/FRANKS**
1 link or frank

**EGGS**
1 medium size
## Instructions

- For more information, hover over the food name.
- Consider the portion size when making your selection.

### WATER
1 cup or 8 fl. oz. = 1 smallest bottle

### SPORTS DRINKS
1 cup or 8 fl. oz. = 1 smallest bottle

### SODA
12 ounce can

### MILK
1 cup or 2 ounces

### SOY MILK
1 cup or 2 ounces

### OTHER MILK
1 cup or 2 ounces

### JUICES
1 cup or 2 ounces

### SMOOTHIES/SHAKES
1 cup or 2 ounces

### COFFEE
1 cup or 2 ounces

### TEA
1 cup or 2 ounces
<table>
<thead>
<tr>
<th>Category</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>MELONS</td>
<td>1/4 cup</td>
</tr>
<tr>
<td>PEACHES/PLUMS/NECTARINES</td>
<td>1 medium or 1/4 cup</td>
</tr>
<tr>
<td>GRAPES</td>
<td>15 grapes</td>
</tr>
<tr>
<td>TROPICAL FRUITS</td>
<td>1 medium or 1/4 cup</td>
</tr>
<tr>
<td>DRIED FRUITS</td>
<td>1/4 cup or a handful</td>
</tr>
<tr>
<td>AVOCADO &amp; GUACAMOLE</td>
<td>1/4 avocado or 1/4 cup guacamole</td>
</tr>
<tr>
<td>SALADS &amp; SALAD GREENS</td>
<td>1 cup raw</td>
</tr>
<tr>
<td>CABBAGE FAMILY</td>
<td>1 cup raw or 1/2 cup cooked</td>
</tr>
<tr>
<td>GREEN &amp; STRING BEANS</td>
<td>1/4 cup cooked</td>
</tr>
<tr>
<td>APPLES/PEARS</td>
<td>1 medium or 1/4 cup</td>
</tr>
<tr>
<td>ORANGES</td>
<td>2 small clementines/mandarin or 1 medium orange</td>
</tr>
<tr>
<td>BERRIES</td>
<td>8 strawberries, 1/4 cup other berries</td>
</tr>
<tr>
<td>BANANA</td>
<td>1 medium</td>
</tr>
<tr>
<td>CANNED/STEWED FRUITS &amp; SAUCES</td>
<td>1/4 cup or 1 container</td>
</tr>
<tr>
<td>LEAFY GREEN VEGETABLES</td>
<td>1 cup raw or 1/4 cup cooked</td>
</tr>
<tr>
<td>SNACK VEGETABLES</td>
<td>1 cup raw or 1/4 cup cooked</td>
</tr>
<tr>
<td>CORN &amp; PEAS</td>
<td>1 medium corn or cob or 1/4 cup corn or peas</td>
</tr>
<tr>
<td>SQUASH</td>
<td>1/4 cup cooked</td>
</tr>
</tbody>
</table>

Instructions

- For more information, hover over the food name.
- Consider the portion size when making your selection.
REFERENCE LIST


