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Association of Sexual Maturation and Body Size of Arfak Children

ELDA IRMA JEANNE JOICE KAWULUR[‡*], BAMBANG SURYOBROTO, SRI BUDIARTI, ALEX HARTANA

Department of Biology, Faculty of Mathematics and Natural Science, Bogor Agricultural University, Darmaga Campus, Bogor 16680, Indonesia

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Gonad maturation in pubertal girls and boys is accompanied with somatic growth spurt, changes in quantity and distribution of body fat (BF), development of secondary sex characters, and relevant physiological events. Menarche (first event of menstruation) and spermarche (first event of nocturnal sperm emission) are usually used as indicators of gonad maturation. We found that median age at menarche of Arfak girls in Manokwari, West Papua is 12.2 years, while median age at spermarche of boys is 13.6 years. A possible factor causing young age at menarche is due to adaptation to unstable environmental conditions because of high risk of mortality by malaria disease during childhood. The events of menarche and spermarche achieved one year after the peak body height (BH) velocity, and just before or at the same time with the time of maximum growth rate of body weight (BW), body mass index (BMI), and BF. The average BMI of Arfak girls was big at 21.9 kg/m^2 at the time of their menarche. Bigger average BMI might be caused by prepubertal slowing down of BH growth compare to growth of BW whichis still increasing. Girls accumulate BF before puberty to be used as an energy reserve for the occurrence of menarche. At the time of development of secondary sexual characters girls use the fat reserve so it decline sharply after puberty. In boys, growth rate of BF was stopped at 11 years old, and then growing negatively presumably because boys use fat mass for the occurence of spemarche. BF growth rate reached the lowest point at the age 16 years old, and then increase linearly with age through adolescence until adulthood at age 23 years old.

Key words: Arfak, menarche, spermarche, body height, body weight, body fat

INTRODUCTION

Gonad maturation in pubertal boys and girls is accompanied with somatic growth spurt, changes in quantity and distribution of body fat (BF), development of secondary sex characters, and relevant physiological events (Marshall & Tanner 1969; Marshall & Tanner 1970; Marshall 1978; Biswas & Kapoor 2004; Hoffman *et al*. 2005). Optimal growth is essential to initiate the processes of menarche (first event of menstruation) and spermarche (first event of nocturnal sperm emmision). The close association between sexual maturation and growth, therefore, plays a role in assessing health condition of population (Bagga & Kulkarni 2000; Keizer-Schrama & Mul 2001; Mitra *et al*. 2002; Reddy & Radhika 2003; Himes *et al*. 2004; Kamal *et al*. 2004; Khanna & Kapoor 2004; Prabhjot *et al*. 2005; Ofuya 2007).

Menarche and spermarche are usually used as indicators of gonad maturation for girls and boys, respectively (Ammari *et al*. 2004; Malina *et al*. 2004; Dakshayani *et al*. 2007). On the other hand, indicators for somatic growth are conventionally sought for in age-related changes in body BH and BW. BH describes the general status of bony skeleton (Loesch *et al*. 1995). Growth of weight relates to changes in fat, muscle, and bone masses (Malina *et al*. 2004). Growth spurt in body size is usually measured based on its rate, age at the peak velocity, and age at take off (Abassi 1998; Malina *et al*. 2004).

There are several hypothesis to explain the association of physical growth to the age at menarche. Simmons and Greulich (1943) proposed that skeletal development is strongly correlated with age at menarche. Chang *et al*. (2000) and Puspita (2004) provide data that peak height velocity reached one year before menarche, then slows down thereafter, and stopped because of the closing of epiphyses in long bones. Therefore, skeletal growth is often used as an accurate predictor of age at menarche. Other hypothesis is the hypothesis of BW by Frisch and Revelle (1970). Frisch and Revelle (1971) and Anderson *et al*. (2003) showed that menarche had a closer association to BW than to BH of the girls. Under-nutrition, which lowers BW, delays the age at menarche (Frisch 1972; Kulin *et al*. 1982; Leenstra *et al*. 2005). On the other hand, increase in BW relates to acceleration of age at menarche (Anderson *et al*. 2003). Still, other hypothesis explains the distribution of BF and level of leptin to relate to age at menarche (Lassek & Gaulin 2007). The study explains that gluteofemoral fat in girls have higher leptin level compared with other parts of the body during puberty.

Study on the association between age at spermarche and growth of body size is rare. Several studies on China, Denmark, France, Hungarian, and Copenhagen present

[‡]Current address: Department of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Papua, Jalan Gunung Salju Amban-Manokwari 98314, Indonesia

[*]Corresponding author. Phone: +62-986-211455, Fax: +62-986-211065, E-mail: irmakawulur@yahoo.com

growth chart of body size, age at spermarche, and urinary excretion of spermatozoa. However, none of these studies showed the relationship between age at spermarche and body size (Schaefer *et al*. 1990; Pedersen *et al*. 1993; Yan *et al.* 1999; Rochebrochard 2000; Ji 2001; Bodzsar & Zsakai 2007; Janssen 2007; Zhu *et al*. 2009). On the other hand in Sragen (center of Java) peak height velocity of the boys is reported to reach at the same time as their age at spermarche; however, their peak weight velocity reached before that (Suratno 2009). Therefore, BW can be used as early indicator of age at spermarche.

Papua (the Netherlands New Guinea, or Irian Jaya) is western part of New Guinea. In Papua there are approximately 269 languages (Mansoben 2007), and thus possibly 269 tribes. They are considered as belonging to Australoid race. Arfak is one of the tribes that inhabit Manokwari, West Papua Province. The tribe is divided into four subtribes: Hattam, Meyah, Sougb, and Moile. They are semi-nomadic people with semi-permanent residence. They live in hunting, gathering, and subsistent farming with shifting cultivation system (Hastanti & Yeni 2009). The study of age at menarche and spermarche has not been done in Arfak tribe, including its association with somatic maturation. The purpose of this study is to determine the age at menarche and spermarche of Arfak children, and to learn how they are indicated by BH and BW.

MATERIALS AND METHODS

Subject. Children and adolescents of Arfak tribe comprised of 231 gorls (ages ranged from 6 to 19 years) and 283 boys (ages ranged from 6-23 years), were observed in Manokwari, West Papua province. A cross sectional study of sexual development and anthropometric measurement was conducted during September 2010 to April 2011. Each subject or parent was explained a complete description and objectives of this study, and only if they understood and agreed to participate that they are included asa sample. They were asked to sign the letter of informed consent, and completed a questionnaire on their child birth dates, ethnicity, and other demographic data.

Measurement. Age was determined by calculating the difference between the date of measurement and the date of birth; it is divided by 365.25 to get age in years (Kuczmarski *et al.* 2002). Age at menarche or age at spermarche was determined based on status quo method (Malina *et al*. 2004).

BW and BH measurements followed manual procedure of NHANES III (1988). Indicator of fat mass used standard formula of World Health Organization (WHO 1995): BMI = BW/BH^2 (kg/m^2). Bio-impendance analysis (OMRON HBF-306) was used to estimate BF.

Data Analysis. Average age at menarche and age at spermarchewas determined by Probit-GLM (Generalized Linear Model) method (Venables & Ripley 1999). Horizontal line drawn from the probability of 50% cuts probit curve at a point. This point is the approximate age of the median age at menarche orage at spermarche.

Growth chart of BH, BW, BMI, and BF were presented at 11 level of percentiles (2.3, 3, 5, 10, 25, 50, 75, 85, 95, 97, and 97.7%) using generalized additive models for location, scale and shape (GAMLSS) (Rigby & Stasinopolous 2005). These chart were based on standard chart with 3 to 97% percentiles which were recommended by WHO for using internationally in the assessment of physical growth and nutritional status of chidren (Kuczmarski *et al*. 2002).In preliminary study, outliers, which were detected as individuals beyond 2.3 and 97.7% percentiles, were eleminated in trying to get norms of growth pattern. Average growth pattern of BH, BW, BMI, and BF were obtained from 50% percentiles.Using this curve, velocity is measuredas theincrease of body size within a year.

Using Kuczmarski *et al*. (2002) and McCarty *et al*. (2006) classification, nutritional statuses based on BMI and BF were determined. A child is defined as underweight if BMI was lower than the value at 5% percentile, at risk for underweight if BMI ranges in the 5 to 15% percentile, normal if BMI ranges in the 16 to 84% percentile, overweight if BMI ranges in the 85 to 94% percentile, and obese if BMI is higher than 95% percentile (Kuczmarski *et al*. 2002). Based on BF, McCarthy *et al*. (2006) selected the 2% percentile to define the upper limit of underfat, and the 85 and 95% percentiles to define the lower limits of overfat and obese.

All anthropometric data were statistically analyzed in the Section of Biosystematic and Ecology of Animals, Department of Biology, Bogor Agricultural University. Statistical procedures were performed using the R software version 2.10.0 (R Development Core Team 2010).

RESULTS

Sexual Maturation and Growth Rate of Body Size. Arfak girls experienced menarche at the age of 12.2 years, while Arfak boys began spermarche at the age of 13.6 years (Figure 1).The relationship between the age at menarche or spermarche and their age-related changes in BH, BW, BMI, and BF are showed in Figure 2 to 5, respectively.

The growth rate of BH in girls started to increase at 9 years old, and reached maximum at the age of about 11 years old, and return to take off at age of 14 years old. In the age of 17 years old, growth rate in height of girls stopped and tend to be negative between 18-19 years old. On the other hand, the rate of BH in boys tended to be stable at the age of 7 to 9 years, started to increase at 10 years, and reached maximum at the age about 13 years, then return to take off at age of 14 years, and declined after that. BH was practically stopped to grow in the age of 22-23 years (Figure 2). The age of puberty of girls and boys were reached one year after their BH grow at maximum rate (Figure 2).

BW growth rate of Arfak girls tended to take off at 9 years old, and continued to increase until reached a peak at age 12 years old, after that the growth rate of BW return to take off at age 15 years old. BW growth rate of Arfak boys started to increase at 9 years old, then reached a

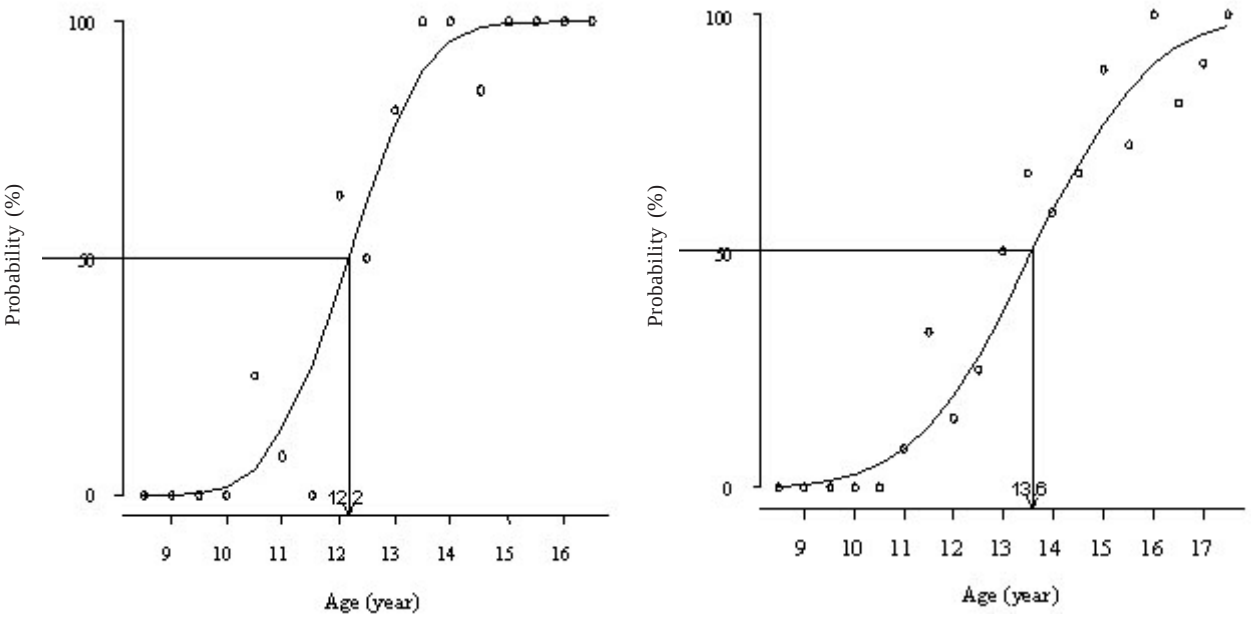

Figure 1. Age at menarche of Arfak girls (left) and age at spermache of Arfak boys (right).

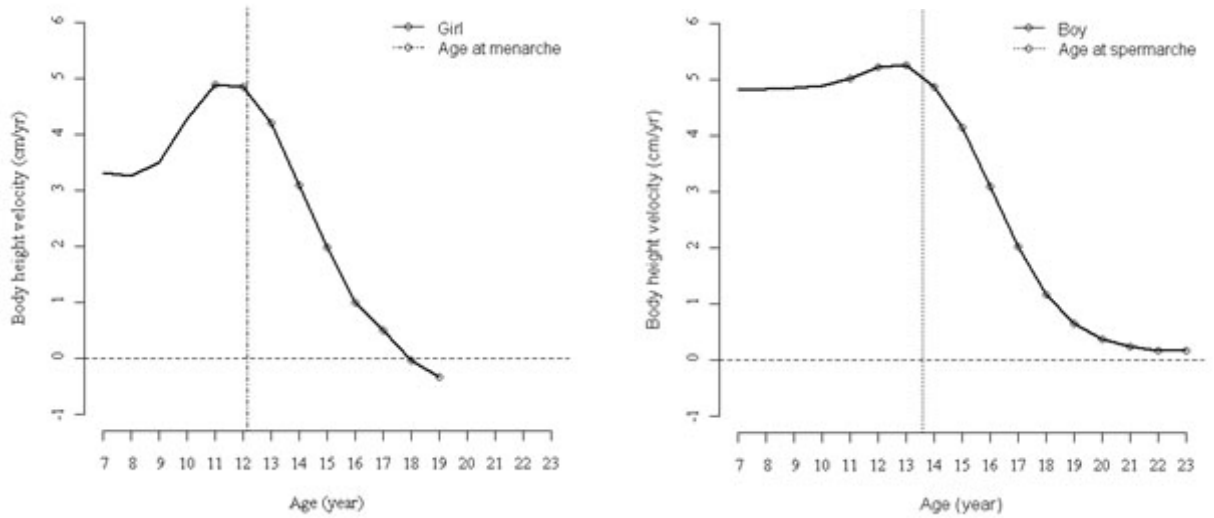

Figure 2. The growth velocity of BH in girls and age at menarche (left), the growth velocity of BH in boys and age at spermarche (right).

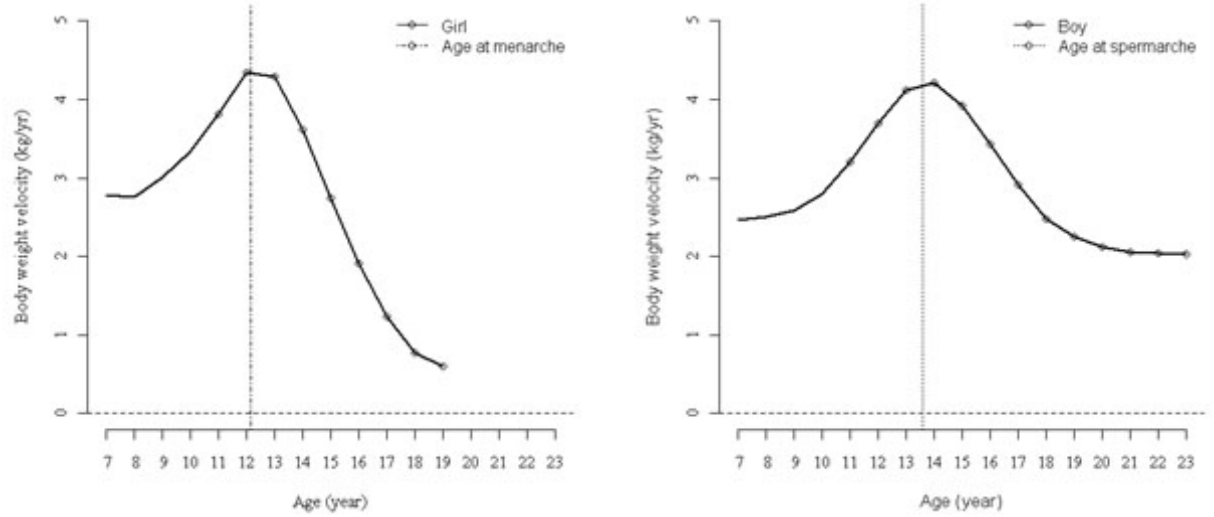

Figure 3. The growth velocity of BW in girls and age at menarche (left), the growth velocity of BW in boys and age at spermarche (right).

peak at 14 years old, after that return to take off at 18 years old, and relatively stable at age 23 years. (Figure 3). Menarche and spermarche age of Arfak children reached at the same time as their maximum BW growth rate.

In Arfak girls, BMI growth rate tended to take off at 9 years old, and continued to increase until a peak at age 13 years old, after that the growth rate of BMI return to take off at age 16 years old; while for Arfak boys BMI growth rate reached the age of take off, peak, and return to take off similar to BW growth rate at the age about 9 years old, 14 years old and 18 years old, respectively (Figure 4). Menarche of girls achieved before growth rate of BMI reached maximum, while age at spermarche of boys reached at the same time as their growth rate of BMI reached maximum. Most Arfak children were categorized healthy since their BMI distribution were between 16-84% percentile.

The growth rate of BF of girls reached maximum at 12 years old, and then decreased sharply, while boys tended to be negative from 11 to 16, then turn to positive (Figure 5). Menarche of girls reached at the same age with maximum growth rate of girls BF, while spermarche of boys reached at the age before the rebound of BF rate.

DISCUSSION

Age at Menarche and Spermarche. The large variation of age at menarche between population is influenced by environment and genetic factors (Zacharias & Wurtman 1969; Graham *et al.* 1999; Thomas *et al.* 2001; Sun *et al.* 2002; Malina *et al.* 2004; Mokha *et al.* 2006). The population of Arfak tended to get menarche (12.2 years) at the same time with or younger than that of Indonesian girls from urban/rural areas and NCHS/WHO reference data(Table 1). People living in urban area tend to have better nutrition and living conditions than those in rural area, thus they might achieve earlier age at menarche.On the other hand, malnutrition and lower standard of living associated with the rural living environment lengthen the age of puberty. The finding in this study reveals an interesting fact that despite approximately 20.3% adolescents of Arfak are categorized as underweight or

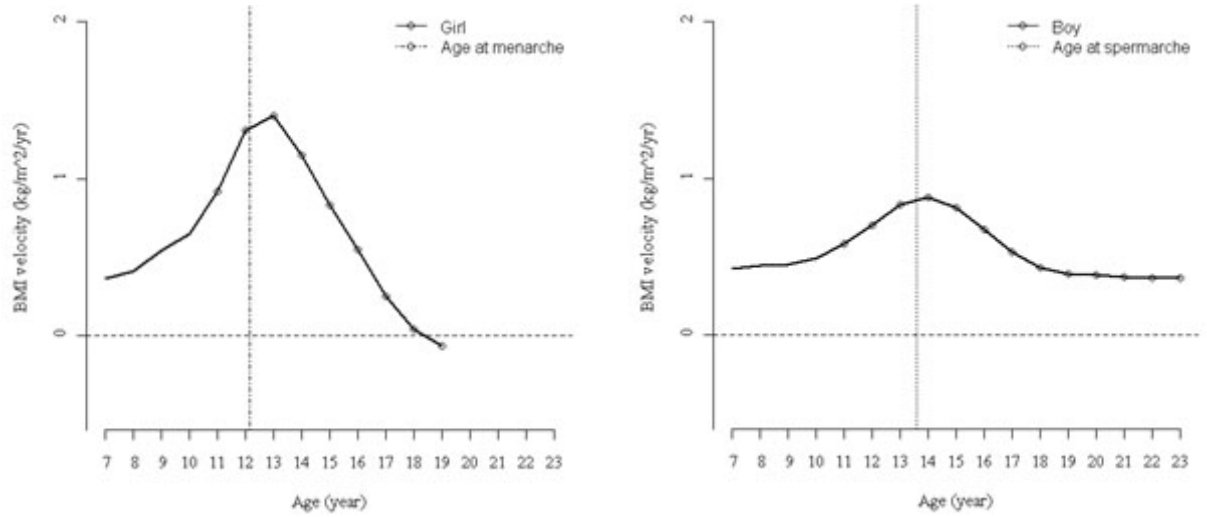

Figure 4. The growth velocity of BMI in girls and age at menarche (left), the growth velocity of BMI in boys and age at spermarche (right).

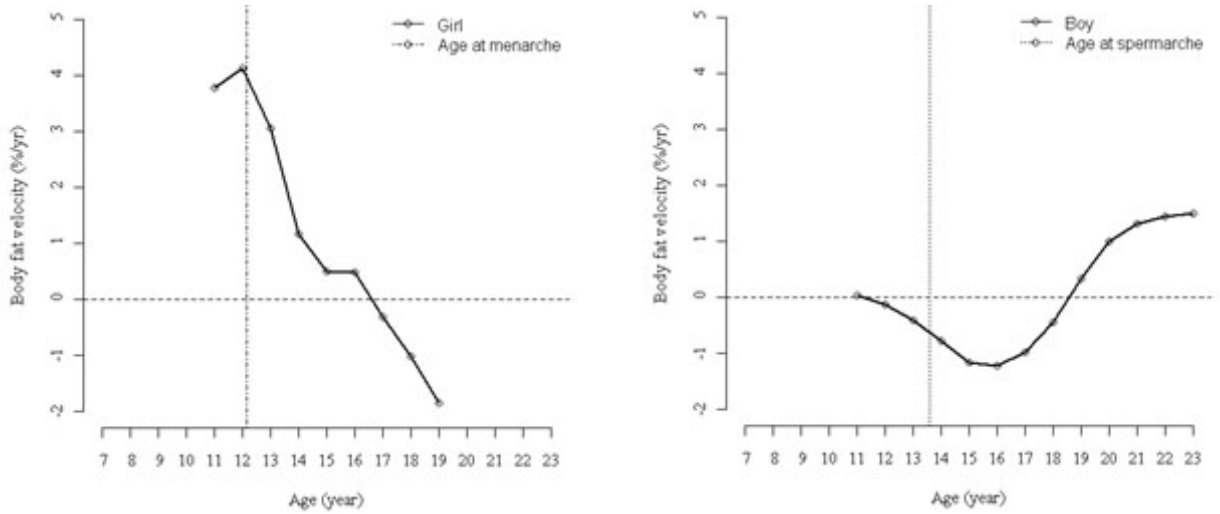

Figure 5. The growth velocity of BF in girls and age at menarche (left), the growth velocity of BF in boys and age at spermarche (right).

malnutrition (Table 2), 79% of their parents are hunter-gatherer and subsistence farmers, and they live in relatively underdeveloped living condition, the age at menarche tended to be earlier than that of Indonesian girl from rural area, or the same with Indonesian girls from urban area.

A possible factor causing younger age at menarche of Arfak girls despite they live in underdeveloped living condition was due to an adaptationto risk of death caused by diseases and malnutrition (Walker *et al.* 2006; Migliano *et al.* 2007). Arfak population lives inrelatively high risk of mortality by malaria disease (Murtihapsari & Chasanah 2010). Based on the global map of malaria endemicity (Hay *et al.* 2009), Papua is the highest prevalent zone in Indonesia. Walker *et al.* (2006) argued that such unstable environment triggers the rapid bodily development in the childhood and juvenile ages, resulting in younger age at puberty. In this adaptive strategy human will shorten their life cycles to optimize their reproduction (Buunk *et al.* 2009). This strategy will increase the chance to contribute their genes to the next generation.

The average spermarcheal age of the Arfak boys (13.6 years) was older compared to that of Javanese boys(12.6 years, Suratno 2009).The sample of children in Java came from families with high socio-economic background that likely were of a factor to accelerate the growth and development leading to puberty. In contrast, they were younger as compared to that in Shaanxi China (13.8 years at urban and 14.2 years at rural,Yan *et al.* 1999), France (14.2 years, Rochebrochard 2000), and Denmark (14.7 years, Zhu *et al.* 2009). The sample of children in Shaanxi-China, France and Denmark came from rural/urban area, and their sosio-economic background varied. The data used in the study of Shaanxi-China was collected at 1995, in France was from 1975 to 1978, and in Denmark was from 1984 to 2005. There is difference in time between present study and data collection of those studies. This difference might lead to secular trend effect on those population which may reduce the ages, so we can say that the Arfak boy tend to have similar age at spermarche with them.

The Association of Sexual Maturation and Body Size. The association of sexual maturation to body size has the same pattern between girls and boys of Arfak tribe. The events of menarche and spermarche achieved one year after the peak BH velocity, and just before or at the same time with the time of maximum growth rate of BW, BMI, and BF.

Young girls gain weight to reach critical values of BMI for the occurrence of menarche. In Javanese population average girls get menarche when they reach BMI of 19.5 kg/m^2 (Suhartini 2007). However the average BMI of Arfak girls was 21.9 kg/m^2 at the time of their menarche which is bigger than that of Javanese girls. Bigger average BMI might be caused by prepubertal slowing down of BH growth comparing to growth of BW which still increasing. This high value of BMI might also be a cause in explaining the lighter BW of Arfak population compare to BW of Colorado population when they get menarche. BW of 46.5 kg at Arfak population is enough compare to 48 kg of Colorado population (Frisch & Revelle 1971) to get menarche because their BMI is big.

Based on two-compartment model of body composition, the body is divided into two parts, fat mass and fat free mass (Lukaski 1987; Ellis 2000; Dorosty *et al.* 2000; Heymsfield *et al.* 2000; Yao *et al.* 2002; Henche & Pellico 2005: Vehrs & Hager 2006). Measurement of BMI (a common indicator for fat mass) and BF play a role in the assessment of human body composition. Before menarche, BF growth rate of Arfak girls tended to increase, and then decrease sharply. Girls accumulate BF before puberty to be used as an energy reserve for the occurrence of menarche.At the time of development of secondary sexual character girls use the fat reserve so it decline sharply after puberty. On the other hand, BMI growth rate also decrease but not sharply compare to BF growth rate. This difference might be caused by development of muscle and bone mass which is still growing after menarche.

In boys, growth rate of BF was stopped at 11 years old, and then growing negatively because boys use fat

Table 1. Variation of age at menarche

Population	Age at menarche (yr)	Life style	Ethnic	Race	Source
Arfak	12.2	Subsistent farmer	Arfak	Australoid	Present study
Naga village	14.5	Rural	Sundanese	Mongoloid	Vidiawati 2009
Pekalongan	13.3	Rural	Javanese	Mongoloid	Ulinnuha 2008
Bogor	12.2	Urban	Sundanese	Mongoloid	Suhartini 2007
Bogor	12.0	Urban	Sundanese	Mongoloid	Ayumi 2002
Jogyakarta	12.3	Urban	Javanese	Mongoloid	Hernawati 2002
NCHS/WHO	12.8	Urban	-	Caucasoid Negroid	WHO 1995

Table 2. Classsification of BF based on Bio-impendance analysis on Arfak children

BF classification	Girls		Boys	
	n = 148	Percentage (%)	n = 217	Percentage (%)
Thin	30	20.3	30	13.8
Thin fat	-	-	5	2.3
Normal	76	51.4	73	33.6
Normal fat	18	12.2	95	44.2
Overweight fat	24	16.2	13	6.0

mass for the occurence of spemarche. BF then showed a phenomenon of adiposity rebound after spermarche. BF growth rate reached the lowest point at the age 16 years old, and then increase linearly with age through adolescence until adulthood at age 23 years old. Several studies show the lowest point of adiposity rebound as indicated by BMI tends to occur at the childhood phase between 5 and 7 years old (Kuczmarski *et al*. 2002; Cole 2004; Malina *et al*. 2004; Williams & Goulding 2009). The pattern of post-spermarchea diposity rebound of Arfak boys which was measured by BF at adolescence phase might be a unique character of Australoid race. This phenomenon is not seen in other growth rate of body size of Arfak children.

In conclusion,in Arfak population average age at menarche is 12.2 years, while average age at spermarche is 13.6 years.Arfak girls showed fast life history strategy as adaptive response to risk of mortality caused by malaria diseases. This factor is potentially important component in understanding the evolution of younger age at menarche of Arfak girls.Gonad maturation of Arfak children achieved one year after the peak of skeletal maturation, and just before or at the same time of maximum growth rate of somatic maturation.Girls and boys accumulate BF before puberty to be used as energy reserve for the occurrence of gonad maturation.

Measurement of first age at reproduction of Arfak tribe was not done in this study. This character is also a plastic response in understanding the human life history.We hope future research will putmore attentionto this character.

REFERENCES

Abassi V. 1998. Growth and normal puberty. *Pediatrics* 102:507-511.

Ammari FL, Ajlouni HK, Ajlouni KM. 2004. Age at menarche in Jordanian girls. *Saudi Med J* 25:244-249.

Anderson SE, Dallal GE, Must A. 2003. Relative weight and race influence average age at menarche: results from two nationally representative surveys of US Girls studied 25 years apart. *Pediatrics* 111:844-850. http://dx.doi.org/10.1542/peds.111.4.844

Ayumi NA. 2002. Pola pertumbuhan anak usia 5 sampai 15 tahun di wilayah Bogor [Skripsi]. Bogor: Fakultas Matematika dan Ilmu Pengetahuan Alam, IPB.

Bagga A, Kulkarni S. 2000. Age at menarche and secular trend in Maharashtrian (Indian) girls. *Acta Biol Szegediensis* 44:53-57.

Biswas RK, Kapoor AK. 2004. Age at menarche and menopause among Saharia women – A primitive tribe of Madhya Pradesh. *Anthropologist* 6:247-252.

Bodzsár EB, Zsákai A. 2007. Changes in the pattern of body components during puberty. *Hum Ecol Special Issue* 15:51-55.

Buunk AP, Pollet TV, Klavina L, Figueredo AJ, Dijkstra P. 2009. Height among women is curvilinearly related to life history strategy. *Evol Psychol* 7:545-559.

Chang S, Tzeng S, Cheng J, Chie W. 2000. Height and weight change across menarche of school girls with early menarche. *Arch Pediatr Adolesc Med* 154:880-884.

Cole TJ. 2004. Children grow and horses race: is the adiposity rebound a critical period for later obesity?. *BMC Pediatrics* 4:1-7. http://dx.doi.org/10.1186/1471-2431-4-1

Dakshayani B, Chandran MS, Gangadhar MR. 2007. Menarche and menopause among the Iruliga tribal women. *Anthropologist* 9:255-256.

Dorosty AR, Emmett PM, Cowin IS, Reilly JJ. 2000. Factors associated with early adiposity rebound. *Pediatrics* 105:1115-1118. http://dx.doi.org/10.1542/peds.105.5.1115

Ellis KJ. 2000. Human body composition: *in vivo* methods. *Physiol Reviews* 80:649-680.

Frisch RE. 1972. Weight at menarche: similarity for well-nourished and under nourished girls at differing ages, and evidence forhistorical constancy. *Pediatrics* 50:445-450.

Frisch RE, Revelle R. 1970. Height and weight at menarche and a hypothesis of critical BWs and adolescent events. *Science* 169:397-399. http://dx.doi.org/10.1126/science.169.3943.397

Frisch RE, Revelle R. 1971. Height and weight at menarche and a hypothesis of menarche. *Arch Dis Childh* 46:695-701. http://dx.doi.org/10.1136/adc.46.249.695

Graham MJ, Larsen U, Xu X. 1999. Secular trend in age at menarche in China: a case study of two rural counties in Anhui province. *J Biosoc Sci* 31:257-267. http://dx.doi.org/10.1017/S0021932099002576

Hastanti BW, Yeny I. 2009. Strategi pengelolann cagar alam pegunungan Arfak menurut kearifan local masyarakat Arfak di Manokwari Papua Barat. *Info Sosial Ekonomi* 9:19-36.

Hay SI, Guerra CA, Gething PW, Patil AP, Tatem AJ, Noor AM, Kabaria CW, Manh BH, Elyazar IRF, Brooker S, Smith DL, Moyeed RA, Snow RW. 2009. A world malaria map: *Plasmodium falciparum* endemicity in 2007. *Plos Medicine* 6:286-302. http://dx.doi.org/10.1371/journal.pmed.1000048

Henche SA, Pellico LG. 2005. Body composition: evaluation methods. *Eur J Anat* 9:117-124.

Hernawati Y. 2002. Hubungan antara status gizi dan pola perkembangan seksual sekunder pada siswi putri SLTP di Kotamadya Yogyakarta [Tesis]. Yogyakarta: Fakultas Kedokteran UGM.

Heymsfield SB, Äez1 CN, Testolin C, Gallagher D. 2000. Anthropometry and methods of body composition measurement for research and field application in the elderly. *Eur J Clin Nutr* 54:S26-S32. http://dx.doi.org/10.1038/sj.ejcn.1601022

Himes JH, Obarzanek E, Baranowski T, Wilson DM, Rochon J, McClanahan BS. 2004. Early sexual maturation, body compositionand obesity in African-American girls. *Obes Res* 12:64S-72S. http://dx.doi.org/10.1038/oby.2004.270

Hoffman WH, Barbeau P, Litaker MS, Johnson MH, Howe CA, Gutin B. 2005. Tanner staging of secondary sexual characteristics and body composition, blood pressure, and insulin in black girls. *Obes Res* 13:2195. http://dx.doi.org/10.1038/oby.2005.272

Janssen DF. 2007. First stirrings: cultural notes on orgasm, ejaculation, and wet dreams. *J Sex Res* 44:122-134. http://dx.doi.org/10.1080/00224490701263595

Ji CY. 2001. Age at spermarche and comparison of growth and performance of pre- and post-spermarcheal Chinese boys. *Am J Hum Biol* 13:35-43. http://dx.doi.org/10.1002/1520-6300(200101/02)13:1<35::AID-AJHB1005>3.0.CO;2-E

Kamal AA, Bener A, Ahmed MA, Al-Mulla K. 2004. Growth pattern of qatari preschool children. *Croat Med J*45:461-465.

Keiser-Schrama D, Mul D. 2001. Trends in pubertal development in Europe. *Hum Repr Update* 7:287-291. http://dx.doi.org/10.1093/humupd/7.3.287

Khanna G, Kapoor S. 2004. Secular trend in stature and age at menarche among Punjabi Aroras residing in New Delhi, India. *Coll Antropol* 28:571-575.

Kuchzmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. 2002. CDC Growth Charts: United States. Advance Data from Vital and Health Statistic no. 314. Hyattsville, Maryland: Center for Disease Control and Prevention/National Center for Health Statistics. http://dx.doi.org/10.1542/peds.109.1.45

Kulin HE, Bwibo N, Mutie D, Santner SJ. 1982. The effect of chronic childhood malnutrition on pubertal growth and development. *Am J Clin Nutr* 36:527-536.

Lassek WD, Gaulin SJC. 2007. Brief communication: Menarche is related to fat distribution. *Am J Phys Anthropol* 133:1147-1151. http://dx.doi.org/10.1002/ajpa.20644

Leenstra T, Petersen LT, Kariuki SK, Oloo AJ, Kager PA, Kuile FO. 2005. Prevalence and severity of malnutrition and age at menarche; cross-sectional studies in adolescent school girls in western Kenya. *Eur J Clin Nutr* 59:41-48. http://dx.doi.org/10.1038/sj.ejcn.1602031

Loesch DZ, Hopper JL, Rogucka E, Huggins RM. 1995. Timing and genetic rapport between growth in skeletal maturity and height around puberty: similarities and differences between girls and boys. *Am J Hum Genet* 56:753-759.

Lukaski 1987. Methods for the assessment of human body composition: traditional and new. *Am J Clin Nutr* 46:537-556.

Malina RM, Bouchard CB, Oder B. 2004. Growth, Maturation, and Physical Activity Second Edition. United States: Human Kinetics.

Mansoben JR. 2007. The Sosio-cultural Plurarity of Papua Society. In: Marshall AJ, Beehler BM, (ed). *The Ecology Indonesian series Vol. VI.The ecology of Papua. Part one*. Washington DC: Conservation International Fondation.

Marshall WA. 1978. The relationship of puberty to other maturity indicators and body composition in man. *J Reprod Fert* 52:437-443. http://dx.doi.org/10.1530/jrf.0.0520437

Marshall WA, Tanner JM. 1969. Variations in pattern of pubertal changes in girls.*Arch Dis Childh* 44:291:303. http://dx.doi.org/10.1136/adc.44.235.291

Marshall WA, Tanner JM. 1970. Variations in the pattern of pubertal changes in boys. *Arch Dis Childh* 45:13-23. http://dx.doi.org/10.1136/adc.45.239.13

McCarthy HD, Cole TJ, Fry T, Je SA, Prentice AM. 2006. BF reference curves for children. *Int J Obes* 30:598-602. http://dx.doi.org/10.1038/sj.ijo.0803232

Migliano AB, Vinicius L, Lahr MM. 2007. Life history trade-offs explain the evolution of human pygmies. *Proc Natl Acad Sci USA* 104:20216-20219. http://dx.doi.org/10.1073/pnas.0708024105

Mitra M, Kumar PV, Ghosh P, Bharati P. 2002. Growth Pattern of the Kamars –A Primitive Tribe of Chhattisgarh India. *Coll Antropol* 262:485-499.

Mokha R, Kaur AI, Kaur N. 2006. Age at menarche in Urban-Rural Punjabi Jat Sikh girls. *Anthropologist* 8:207-209.

Murtihapsari, Chasanah E. 2010. Potensi penemuan obat antimalaria baru dari laut Indonesia. *Squalen* 5:86-91.

[NHANES III] National Health and Nutrition Examination Survey III. 1988. Body measurement (Anthropometry). Rockville: Westat Inc.

Ofuya ZM. 2007. The age at menarche in Nigerian adolescents from two different socioeconomic classes. *J Health Allied Sci* 6:1-4.

Pedersen JL, Nysom K, Jorgensen M, Nielsen CT, MuAller J, Keiding N, Skakkeblek NE. 1993. Spermaturia and puberty. *Arch Dis Child* 69:384-387. http://dx.doi.org/10.1136/adc.69.3.384

Prabhjot, Kaur N, Marwaha G, Sidhu S. 2005.Growth pattern of affluent school children of Amritsar. *Anthropologist* 7:261-264.

Puspita T. 2004. Pola pertumbuhan tinggi badan, berat badan, dan indeks massa tubuh anak Bogor usia 5 sampai 15 tahun [Skripsi]. Bogor: Fakultas Matematika dan Ilmu Pengetahuan Alam, IPB.

R Development Core Team. 2010. R: A Language and Environment for Statistical Computing.Vienna: R Foundation for Statistical Computing.

Reddy BKC, Radhika P. 2003. Age at menarche and some bio-social factors among the girls of Nellore, Andhra Pradesh. *Anthropologist* 5:215-216.

Rigby RA, Stasinopoulos DM. 2005. Generalized additive models for location, scale and shape. *Appl Statist* 54:507-554. http://dx.doi.org/10.1111/j.1467-9876.2005.00510.x

Rochebrochard de la E. 2000. Age at puberty of girls and boys in France measurements from a survey on adolescent sexuality. *Population: An English Selection* 12:51-80.

Schaefer F, Marr J, Seidel C, Tilgen W, Scharer K. 1990. Assessment of gonadal maturation by evaluation of spermaturia. *Arch Dis Child* 65:1205-1207. http://dx.doi.org/10.1136/adc.65.11.1205

Simmons K, Greulich W. 1943. Menarcheal age and the height, weight, and skeletal age of girls aged 7 to 17 years. *J Pediatrics* 22:518-548. http://dx.doi.org/10.1016/S0022-3476(43)80022-6

Suhartini R. 2007. Tahap-tahap kematangan seksual perempuan di wilayah Bogor [Skrpsi]. Bogor: Fakultas Matematika dan Ilmu Pengetahuan Alam, IPB.

Sun SS, Schubert CM, Chumlea WC, Roche AF, Kulin HE, Lee PA, Himes JH, Ryan AS. 2002. National estimates of the timing of sexual maturation and racial differences among US children. *Pediatrics* 110:911-919. http://dx.doi.org/10.1542/peds.110.5.911

Suratno. 2009. Usia maturasi seksual dan pertumbuhan badan laki-laki kabupaten Sragen [Tesis]. Bogor: Fakultas Matematiak dan Ilmu Pengetahuan Alam, IPB.

Thomas F, Renaud F, Benefice E, De Meeüs T, Guegan J. 2001. International variability of ages at menarche and menopause: patterns and main determinants. *Hum Biol* 73:271-290. http://dx.doi.org/10.1353/hub.2001.0029

Ulinnuha DF. 2008. Usia menarke dan perkembangan payudara perempuan di pedesaan Kabupaten Pekalongan [Skripsi]. Bogor: Fakultas Matematika dan Ilmu Pengetahuan Alam, IPB.

Vehrs P, Hager R. 2006. Assessment and interpretation of body composition in physical education. *J Phys Edu* 77:46-51.

Venables WN, Ripley BD. 1999. Modern applied statistic with S-Plus. New York: Springer Inc.

Vidiawati V. 2009. Jangka reproduksi wanita kampung Naga [Skripsi]. Bogor: Fakultas Matematika dan Ilmu Pengetahuan Alam, IPB.

Walker R, Gurven, Hill K, Migliano A, Chagnon N, Souza N, Djurovic G, Hames R, Hurtado AM, Kaplan H, Kramer K, Oliver WJ, Valeggia C, Yamauchi T. 2006. Growth rates and life histories in twenty two small scale societies. *Am J Hum Biol* 18:295-311. http://dx.doi.org/10.1002/ajhb.20510

[WHO] World Health Organization. 1995. Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Consultation. WHO technical report Series Number 854. Geneva: World Health Organization.

Williams SM, Goulding A. 2009. Patterns of growth associated with the timing of adiposity rebound. *Obesity* 17:335-341.

Yan H, Dibley MJ, D'Este K, Hou R. 1999. The national survey on the constitution and health of Chinese students in 1995: Nutritional status of school students aged 10-17 years in Shaanxi, China. *Asia Pacific J Clin Nutr* 8:121-128. http://dx.doi.org/10.1046/j.1440-6047.1999.00079.x

Yao M, Roberts SB, Ma G, Pan H, McCrory MA. 2002. Field methods for body composition assessment are valid in healthy Chinese adults. *J Nutr* 5:310-317.

Zacharias L, Wurtman RJ. 1969. Age at menarche. Genetic and environment influences. *New England J Med* 280:868-875. http://dx.doi.org/10.1056/NEJM196904172801606

Zhu JL, Basso O, Obel C, Bech BH, Nohr EA, Shrestha A, Olsen J. 2009. Parental infertility and sexual maturation in children. *Hum Reprod* 24:445-450. http://dx.doi.org/10.1093/humrep/den366