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Physical Growth of Sasak Children at Different Altitudes in Lombok Island

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The physical growth that occurs in schoolage children makes this period one of the most important phases in the human life cycle. Within this period, puberty is indicated by growth spurts that increase both stature (BH) and bodyweight (BW). The focus of this research was to evaluate the age-related body size variation in Sasak children living at different altitudes on the island of Lombok, Indonesia: low, medium, and high. Our results showed that children living at low altitude were taller and heavier than children of the same age living at medium and high altitudes. Up until the onset of puberty, the children at medium altitude have similar stature and weight to those residing at high altitude, but they are shorter and lighter thereafter. There were significant differences in the height and weight of girls in different altitude locations, but no significant difference for boys. The effect of SES on child growth can be comparison between Sasak and other populations in Indonesia. In general, the Sasak children are shorter and lighter than children of the same age in urban populations, and relatively similar in size to the children in rural populations. Indicators of socioeconomic status such as family income and parental education were shown to be more influential factors in the differentiation of physical growth between populations than the altitude factor

Key words: altitude, growth, stature, body weight, Sasak

INTRODUCTION

The human life cycle can be classified into stages as follows: neonatal (birth to 28 days), infancy (1 to 36 months), childhood (3 to 7 years), juvenile (7 to 12y), puberty (transition between juvenile to adolescence; lasting for days or few weeks at 12 to 15y), adolescence (5 to 8y after the onset of puberty), adulthood (20y to end of child-bearing years), and senescence (end of child-bearing years to death). The age of schooling (6 to 20y) is one of the important phases in human life cycle because during these years, the body changes significantly in size, structure, proportions, and composition (Bogin 1999). Within this age range, the stage of puberty is indicated by growth spurts that increase stature (BH) and bodyweight (BW). These two characters are anthropometric measurements used to determine the body size.

Both genetic and environmental factors contribute to body shape and size variations during development. For instance, children who live in high altitude environments face numerous stresses, including hypoxia, cold climate, ultraviolet radiation, and rough and difficult terrain. These conditions require greater physical and physiological activity from children, than the conditions in low altitude (Hastuti 2005; Malhotra *et al*. 2006; Singh *et al.* 2007). Several studies show a pattern low birth weight and reduced childhood growth in people living at high altitude (Yip *et al*. 1988; Jensen & Moore 1997; Lestari 2006). However, other studies have found little or no difference in growth between children living at low and high altitudes (Freyre & Ortiz 1988; Hastuti 2005). Socioeconomic statuses (SES), such as parent education, occupation and monthly income, widely influence the growth of children (Eiben & Mascie-Taylor 2004; Bener & Kamal 2005; Bala *et al.* 2010; Lazzeri *et al*. 2011; Widiyani *et al*. 2011).

The focus of this research was to evaluate the age-controlled variation in body size of Sasak children residing at different altitudes. Our subjects were Sasak school children who live on Lombok Island, Indonesia at one of three different altitudes; that is, low, medium, and high altitudes. We found significant differences in BH and BW between girls at different altitudes, but no such difference for boys. Overall, children in low altitude populations were taller and heavier than children from medium- and high-altitude populations. Until puberty, the children at medium

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altitude have similar stature and weight to same-aged children that reside at high altitude; however they are shorter and lighter thereafter. Family income and parental education, rather than the altitudinal factor, exerted more influence on the differentiation.

MATERIALS AND METHODS

Subject. The subjects in this research are children of the Sasak ethnic who live at different altitudes in Lombok Island, West Nusa Tenggara province, Indonesia. A cross sectional sampling was conducted from July to December 2012. Population samples were taken of students from kindergarten to senior high school-age, aged 3 to 19y (Table 1). All subjects are rural children who lives in one of 3 altitudes: low (16 to 28 m above sea level), medium (525 to 628 m asl), and high altitudes (1130 to 1213 m asl). A Global Positioning System (Garmin Etrex 10 GPS) was used to determine the altitude. Before embarking on the present research, a letter with detailed information about this study was sent to the parents or guardians of children in the kindergarten and elementary school samples to ask their consent for their child's participation. Junior and senior high school subjects were asked directly for their informed consent. If they agreed to participate, they were asked to sign the informed consent form and to complete a questionnaire on demographic and socioeconomic status. Data analysis was conducted at Section of Biosystematics and Ecology of Animals, Department of Biology, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University.

Measurements. BH is a linear measurement, for a standing person, of the distance from the standing surface to the top (vertex) of the skull; it is a composite of linear dimensions contributed by the lower extremities, the trunk, the neck, and the head. It was measured to the nearest 1 mm using anthropometer. BW is a measure of body mass; it is a composite of independently varying tissues. BW was measured using digital weight scale with 100 g resolution.

Sosioeconomic Status (SES). The SES of the children was ascribed to them based on the SES of their parents. SES is a concept that encompasses aspects of formal education (schooling), occupation and monthly income (Bogin 1999). Six educational levels, ten occupational categories and five monthly incomes of parents were used to identify the SES. The regional minimum wage UMP (Upah Minimum Provinsi) of West Nusa Tenggara (Nusa Tenggara Barat, NTB) province was used as a benchmark for family income. UMP is regulated every year by local government based on the rates of several goods essential to life in an area. It is a standard used by industry in paying their single (unmarried, no family) male laborers or employees. The regional minimum wage of NTB in 2013 is IDR 1,100,000.

Data Analysis. Growth data for BW and BH were charted against age, and were fitted by applying generalized additive models for location, scale and shape (GAMLSS) (Rigby & Stasinopoulos 2005). We predicted nine percentile-increments (3, 5, 10, 25, 50, 75, 90, 95, and 97%) to describe the pattern of growth. Velocity is the rate of growth (cm/y or

Table 1. Site sampling of Sasak children

Name of the school	Number of samples
Low altitude	408
TK Satu Atap SD 1 Labuan Tereng , West Lombok	19
SD 1 Labuan Tereng, West Lombok	31
SD 4 Batulayar, West Lombok	46
SMP 1 Batulayar, West Lombok	144
SMK Pariwisata Batulayar, West Lombok	126
SMK Perikanan Lembar, West Lombok	42
Medium altitude	271
PAUD Mawar Rindang Tetebatu, East Lombok	19
SD Sekedek, Central Lombok	96
SMP 3 Batu Kliang Utara, Central Lombok	82
MA Nurussalam Tetebatu, East Lombok	74
High altitude	273
PAUD Sembalun Bumbung, East Lombok	17
SD 2 Sembalun Bumbung, East Lombok	113
SMP 2 Sembalun Bumbung, East Lombok	86
SMA 1 Sembalun, East Lombok	57
Total	952

TK and PAUD are Kindergarten School Level; SD is Elementary School Level; SMP is Junior High School Level; SMA, SMK and MA are Senior High School Level.

kg/y) (Malina *et al*. 2004). Median values were used to calculate annual velocity from our data (Kuczmarski *et al.* 2002). In order to evaluate the variation in body size of sample groups at different altitudes we computed the Z value of each individual. The Z score is based on the statistical population mean, and measured in units of standard deviations. By using the Z score of BH and BW, we effectively eliminated the effect of age on changes on body size. One-way ANOVA was used to evaluate effect of altitude on body size in each sex group. The Tukey HSD (honest significant difference) *post hoc* test was used to evaluate the differences between each pair of altitudes. The effect of SES on child growth can be comparison between Sasak and other populations in Indonesia. All statistical procedures were performed using the R software version 2.9.1 (R Development Core Team 2010).

RESULTS

Socioeconomic Backgrounds. The subjects from low altitude population consisted of 203 boys and 205 girls from two villages, Batu Layar and Labuan Tering, located at coastal areas. One third of fathers in this group were laborers (with a majority of them working in brick production, construction, and as porters in the local traditional markets), one fifth fishermen, and 17% of them merchants. A half of their mothers were not working or housewives, one fifth were merchants and 15% laborers in brick production or as home servants. Over half of the subjects' parents (50% of fathers and 56% of mothers) received only a primary school education; 28 and 18% attended secondary school (junior and senior high school) and only 0.5 to 4% of parents graduated from college (2-year and bachelor degrees). One fifth of parents had no formal education at all.

The children in the medium altitude category live in agricultural villages near Rinjani National Park. The subjects comprised of 123 boys and 148 girls from three villages (Setepak, Seteleng, and Tete Batu). A half of their fathers work as farmers and the others (30%) work as laborers (in brick production, construction, and as overseas migrant workers) or are unemployed (20%). A third of their mothers (34%) were not working or housewives, 30% worked as farmers, and the remainder as laborers or independent harvesters of natural products. This group has a high percentage (50%) of parents without any formal education. Thirty six percent received primary school only, and the rest completed secondary education through high school.

The children in our high altitude category live in agricultural villages at Rinjani Mountain. Subjects from this group consisted of 133 boys and 140 girls from four villages (Sembalun Lawang, Sembalun Bumbung, Jorong, and Telaga). A large majority (86%) of their fathers are farmers. Over half (52%) of mothers also work as farmers and 26.13% of them don't work or are housewives. About a third of fathers (37%) and over half of mothers (58%) from this group received no formal education; a third of them attended elementary school, one fifth of fathers and 10% of mothers received any secondary education and only 3% of the parents hold a high school diploma and college educated.

The majority of families at all altitudes are of small size, with one to three children. The total monthly income of parents in all altitudes is categorized as low or very low. On average, their monthly income is lower than UMP of NTB. Notably, the majority of parents are self-employed (farmers, fishermen, and independent construction laborers) with unstable monthly income.

Stature. The relationship between age and BH is shown in Figures 1 and 2. Examining the 50th percentile data, 3 years old girls from all altitudes in Sasak measure 89 to 91 cm BH. The measurements taken of girls aged 19 years show a divergence between groups at different altitudes: the median stature of girls from both low and high altitude was 160 cm, while the girls in the medium altitude category of the same age measured only 146 cm. The same trends in age-height relationship was seen in boys. The 3y boys from low altitude areas measure 93 cm height, and the 19 year old boys reach 165 cm; whereas the boys in high altitude measured 93 cm at 3 years of age and a maximum of 170 cm at 19 years old. The boys from the medium altitude group had the smallest body height (86 cm for 3 year olds; and 161 cm for 19 year olds).

In early development, the growth rate of BH in girls of low and medium altitudes were relatively stable (Figure 3). Growth velocity started to decline at age 6.5 in lowland populations. For children age 15.5y, growth velocity flattened at 2.3 cm year^{-1}. The girls in the medium altitude population showed almost no velocity at age 15.5y and tend to grow negatively between 16.5 to 18.5y. The growth rate for girls in the highland group started to increase at 3.5 years of age, with velocity at 4.4 cm year^{-1}. Velocity reached its maximum in the age 10.5 years old, with acceleration of 6 cm year$^{-1,}$ and decreased after that. For the girls aged 18.5 years, the velocity for the highland group was relatively stable at 2.6 cm year^{-1}.

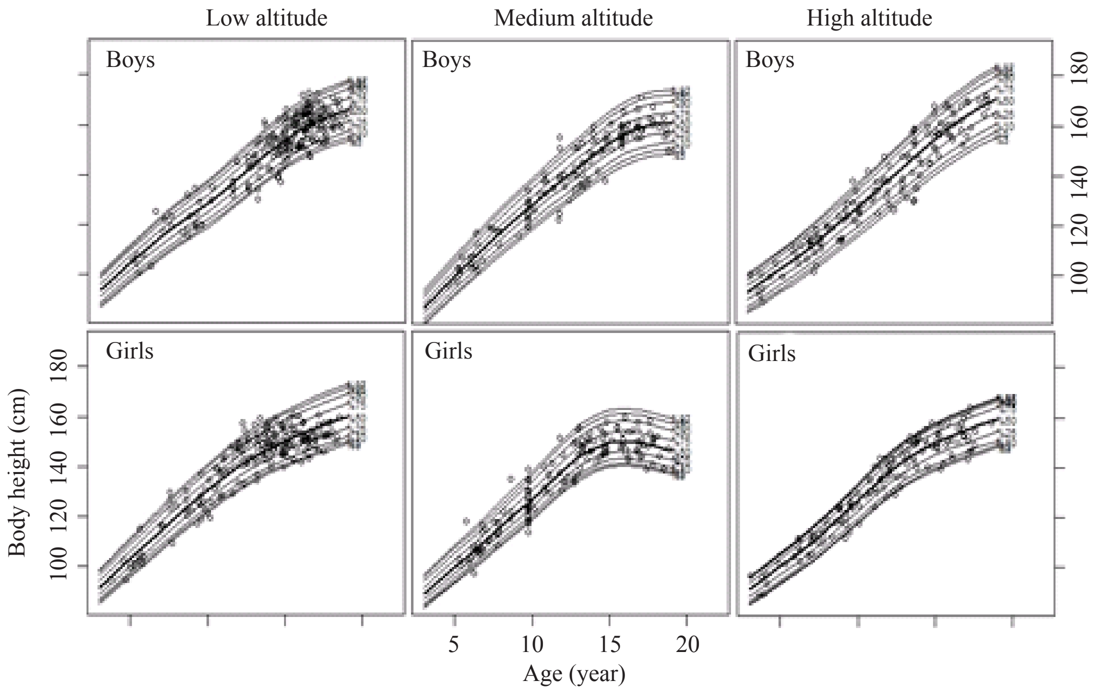

Figure 1. Height-to-age plot of Sasak boys and girls aged 3 to 19 years living at different altitudes.

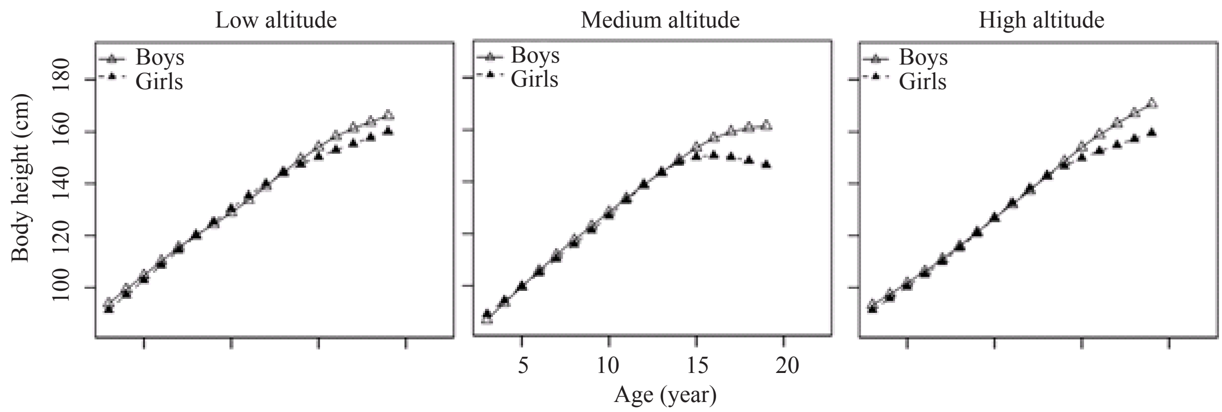

Figure 2. Rates of growth in body height of Sasak children. The data points represent the 50th percentile height measurement for each age (Figure 1). Boys, open; girls, closed.

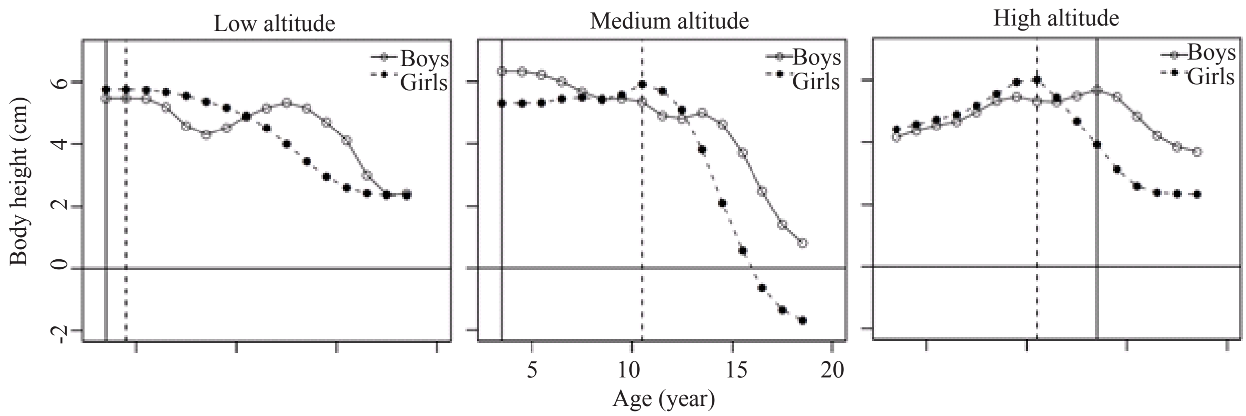

Figure 3. Annual rates of increase in growth (BH) of Sasak children. The data points represent the 50th percentile height measurement for each age. Boys, open; girls, closed. Peak height velocity (vertical line).

The BH growth rate for the low altitude category was relatively stable for boys aged up to 5.5y, and decreased for children between 5.5 and 9.5 years of age. Growth rate increased for the next older children, reaching a maximum velocity for those aged 12.5, when it then declined through age 19. The growth velocity of BH for the medium altitude category decreased from 6.3 cm year^{-1} for boys aged 3.5y, to

0.78 cm year^{-1} for boys aged 18.5y, and no pubescent growth spurt was detected. By contrast, we measured a pubescent "growth spurt" in boys at high altitude, with velocity reaching its maximum for boys aged 13.5y and declining for older boys.

Based on our calculated Z score values, both girls and boys in lowland regions have above average stature, as indicated by a positive mean Z score value (0.2346 for girls and 0.1089 for boys). On the other side, the average stature of children from our medium and high altitudes-groups are below the population mean with negative Z score values. According to the ANOVA analysis (Table 2), elevation significantly influenced body height in girls ($P < 0.05$) but not in boys ($P > 0.05$).

Tukey's Honest Significant Difference test was used to determine whether each of our sample groups differ from each other. Based on this test, we found significant difference between body height of girls in the low vs. medium- and high-altitude groups, with $P < 0.05$, however there was no difference between the girls in the medium vs. high altitude groups (Figure 4).

Weight. Data on the 50th percentile of body weight (Figure 5 and 6), showed that 3 year-old girls of the Sasak ethnic living in all altitudes measure 8 to 11 kg in BW. Difference in BW became apparent in the girls aged 19y, where the body weight of girls from low and high altitude groups was 52 kg, but only 43 kg for girls of the same age at medium altitude. 3y boys from the low altitude group weighed 10 kg with BW measured at 53 kg for the 19 year old boys. The 3-year-old boys at medium altitude weighed 9 kg and the 19 year old boys weighed 51 kg. For the high altitude group, the boys measured 12 kg and 57 kg, respectively, at the same ages.

In Figure 7, data shows that the rate of BW growth of girls from all altitudes started to increase for girls aged 6.5 to 7.5y, with velocities of 2.6, 1.4, and 1.7 kg year^{-1} (low, medium, and high altitudes, respectively). Peak velocity was achieved for all groups, between ages 11.5 and 12.5y with velocity 3.1, 4.1, and 4.1 kg year^{-1} and then velocity decreased thereafter. BW velocity remained relatively stable for girls aged 17.5 to 18.5, with velocity measured at 2.5 kg year^{-1} for girls in low and highland groups, but zero growth for

Table 2. One-way ANOVA results of BH and BW in Sasak children

	Df	Sum of square	Mean square	F value	Pr (>F)
Body height (BH)					
Girls elevation	2	15.52	7.76	7.9763	0.000394***
Residuals	453	440.62	0.97		
Boys elevation	2	4.56	2.28	2.287	0.1027ns
Residuals	451	449.43	1.00		
Body weight (BW)					
Girls elevation	2	16.62	8.31	8.563	0.0002239***
Residuals	453	439.57	0.97		
Boys elevation	2	1.18	0.59	0.5859	0.557ns
Residuals	451	452.83	1.00		

*** P<0.001, ns = not significant.

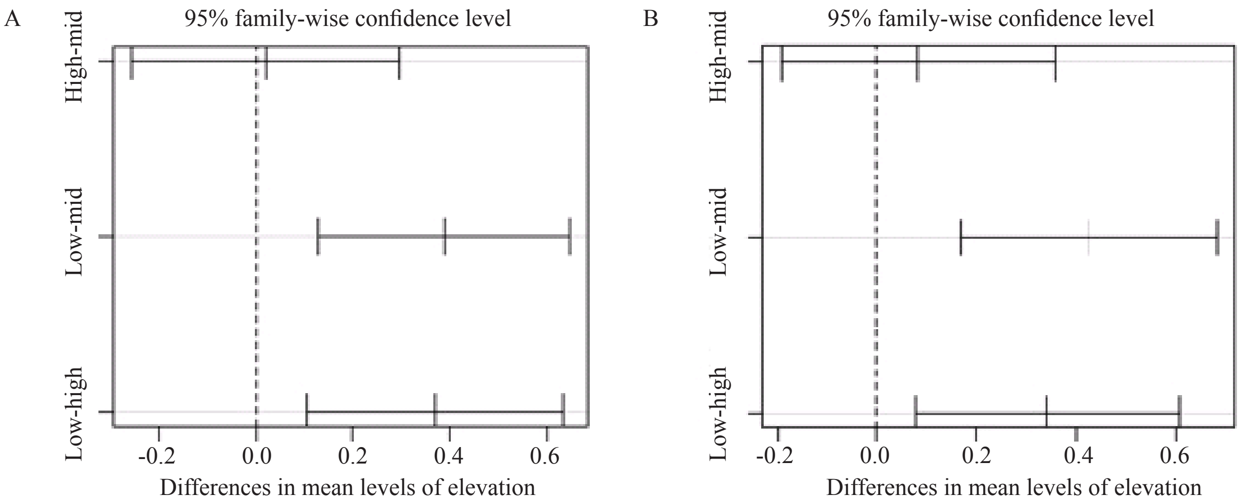

Figure 4. Tukey HSD test of (A) Body height and (B) Body weight of Sasak girls in each altitude.

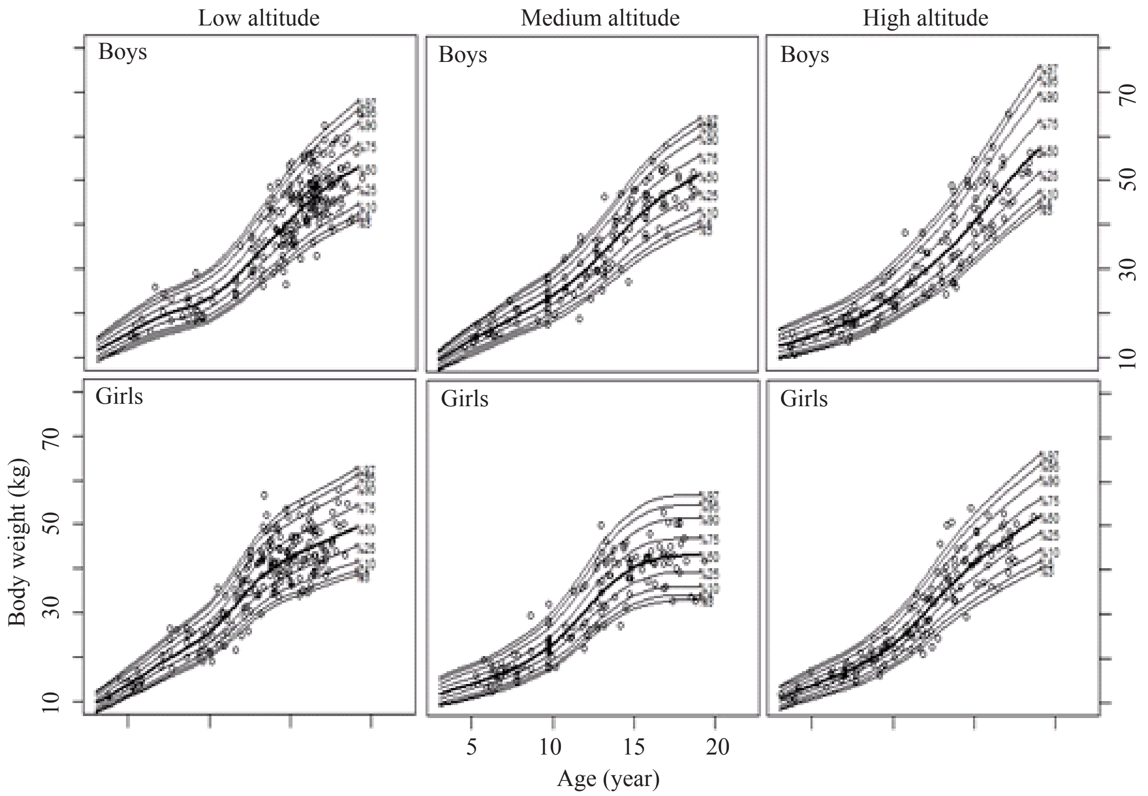

Figure 5. Weight-to-age percentiles of Sasak boys and girls aged 3 to 19 years at different altitudes.

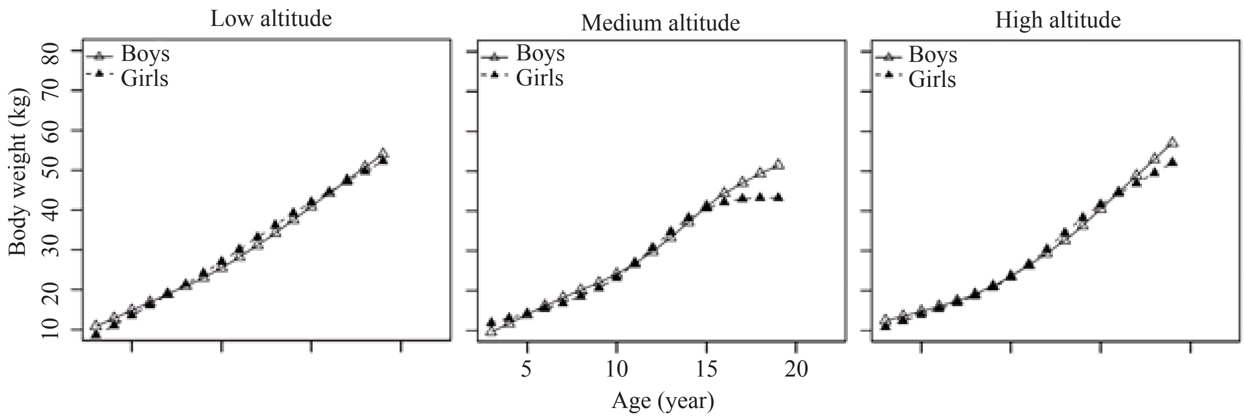

Figure 6. Rates of growth in body weight of Sasak children. The data points represent the 50th percentile BW measurement for each age (Figure 4). Boys, open; girls, closed.

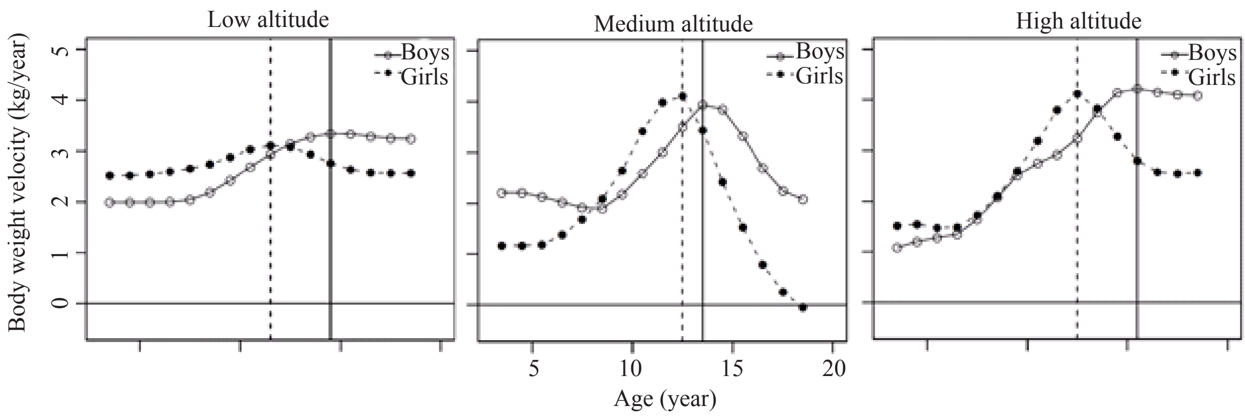

Figure 7. Annual rates of increase in body weight of Sasak children. The data points represent the 50th percentile BW measurement for each age. Boys, open; girls, closed. Peak weight rate (vertical line).

girls of the same age at medium altitude. The BW velocity for boys raised in all altitudes was relatively stable through age 7.5y, increased after that, and reached maximum for boys aged 13.5 years. The BW velocity for boys in the medium altitude group decreased after age 14.5y, while the velocity for the boys at low and high altitude remained stable through age 19.

Our calculations show that the children in our lowland category have above-average weight with a mean Z score of 0.2458 for girls and 0.0577 for boys. Both the children in the medium group and in the high altitude groups exhibited average weights below the population mean, with a negative Z score. Analysis of variance showed a significant influence of elevation on body weight in Sasak girls but not in the boys (Table 2).

According Tukey's Honest Significant Difference test, the body weight of girls in low altitude significantly differed from that of the girls at medium and high altitudes (with P < 0.05). However, there was no significant difference in body weight between girls from medium vs. high altitude locations (with P > 0.05) (Figure 4).

DISCUSSION

Genetic and enviromental factors affect the physical growth and development of children. Sex, age, and ethnic represent the genetic factors. Environmental factors include items such as SES, human activities and location of residence. Hypoxic stress in high altitude is one environmental factor that has been shown to delay and modify the pubescent growth spurt in children (Malhotra *et al*. 2006). Altitude is inversely correlated with oxygen content in the air: the higher altitude, the lower the oxygen content. The reduction in partial pressure of oxygen is more significant above 3000 m altitude (Virués-Ortega *et al.* 2006). As expected, Hastuti (2005) reported no significant differences in BH or BW between girls and boys; nor between those living in Samigaluh (high altitude, less than 1000 m asl) vs. Galur districts (low altitude, coastal area) at Kulon

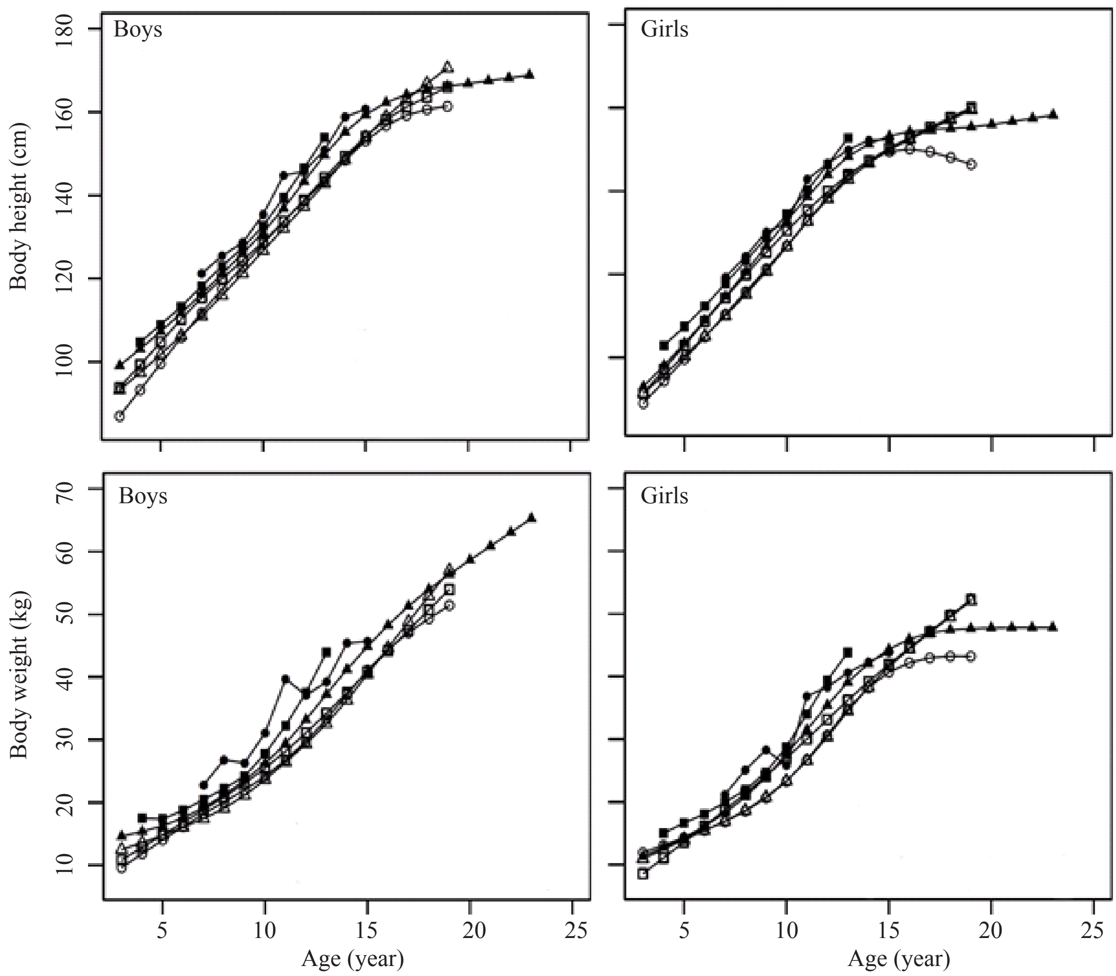

Figure 8. Body height and body weight comparison of Sasak vs. several urban populations in Indonesia. Sasak low (present study), Sasak medium (present study), Sasak high (present study), Karawang (Hermawan 2007), Yogyakarta (Rahmawati *et al*. 2004), Magelang (Widiyani *et al*. 2011).

Progo regency, Indonesia. These results indicate that altitude below 3000 m asl has relatively little effect on body size. However, in our study, Sasak girls residing at low altitude (16 to 28 m asl) were taller at age 3 to 12y and heavier at age 6 to 14y, than girls of the same age living at medium altitude (525 to 628 m asl) and high altitude (1130 to 1213 m asl). These differences were statistically significant. The same trends were observed in boys across different altitudes, but the altitudinal differences were not statistically significant. Both children of both sexes residing at medium altitude have similar stature and weight to the population age 5 to 15y who reside in high altitude. However, after 15 years of age, the population at medium altitude were shorter and lighter than the population at high altitude. The populations as ranked by biggest to smallest body sizes, were those at low, high and medium altitudes respectively. There is evidence that the high altitude children have lower stature in part caused by their smaller size at birth. Infants born at high altitude (especially in more than 1500 m asl) often experience intrauterine growth restriction (Jensen & Moore 1997; Lestari 2006). We lacked the data necessary to not compare the neonatal body size of Sasak children at each altitude. Regarding the population of Sasak children at medium altitude, we should not expect 500 m asl altitude to generate adverse effects on intrauterine growth and newborn body size. Therefore the difference in body size we found in girls at different altitudes might be better explained by differences in SES.

Family income and parental education are commonly-used indicators of SES (Julia *et al*. 2004; Moestue & Huttly 2008). In low altitude areas, 88.7% of parents have monthly income below the regional minimum wage of 1,100,000 IDR; whereas 91.3 and 92.4% of parents have monthly income below minimum wage, in high and medium altitudes, respectively. The majority of parents in low altitude areas were fishermen, while in medium and high altitude areas were farmers. This presented an advantage to the children in lowland areas in having higher intake of protein (especially fishes

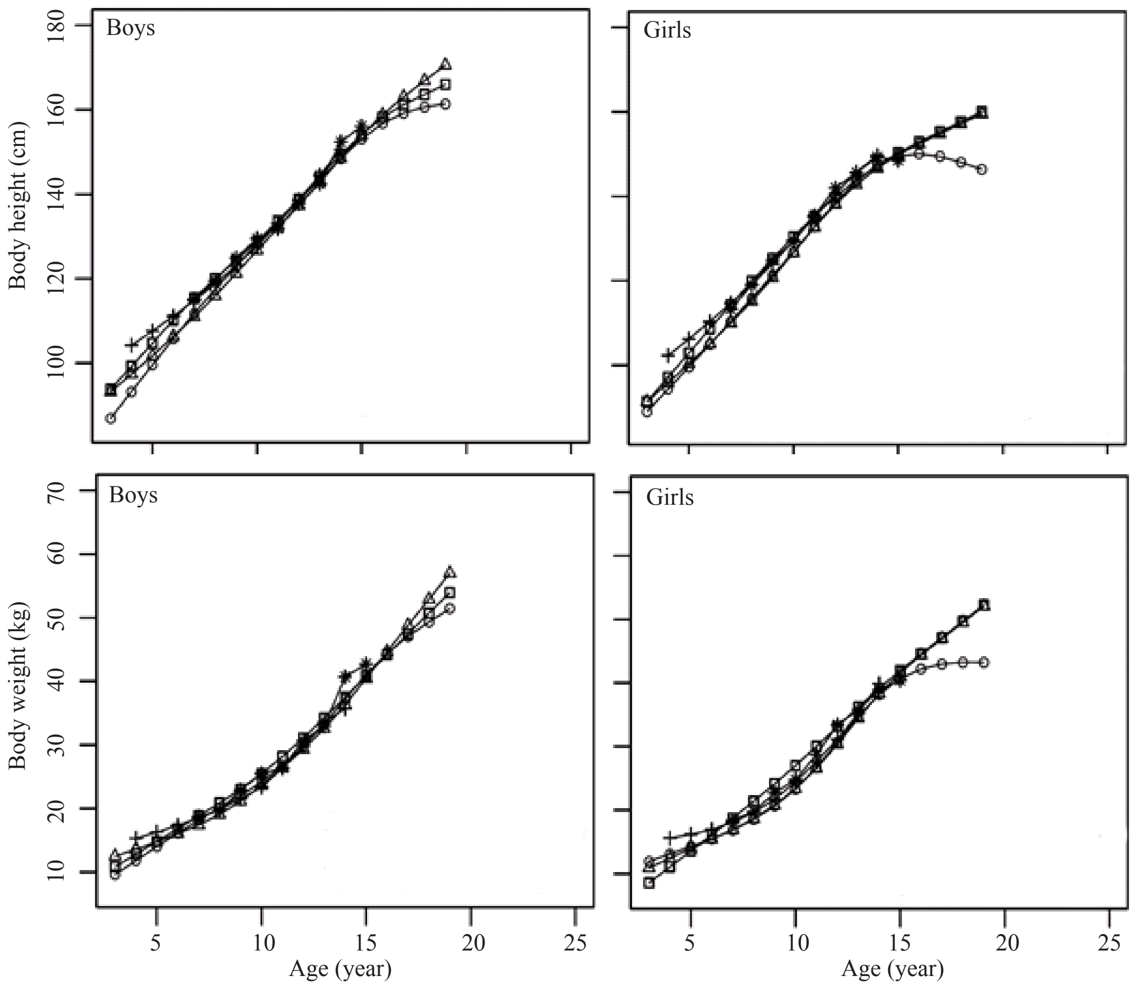

Figure 9. Body height and body weight comparison of Sasak vs. several rural population in Indonesia. Sasak low (present study), Sasak medium (present study), Sasak high (present study), Purwakarta (Miharja 2008), Bantul (Rahmawati *et al*. 2004).

and sea food). Leonard *et al.* (2000) reported the influence of dietary quality on the growth of costal and highland chlildren. The animal energy and protein consumption have a positively corelated with linear growth of BH and BW in costal children and negatively correlated in highland population. The children living at medium and high altitudes have lower SES than those at low altitudes, as reflected in the greater proportion of parents without formal education at the higher elevations. These differences in family income and parental education seem to be a greater influence on body size differentiation than the altitude factor.

The effect of SES on child growth can also be seen in the comparison between Sasak and other populations in Indonesia. Growth of children has been studied at several populations in Indonesia such as Bantul and Yogyakarta (Rahmawati *et al*. 2004), Karawang (Hermawan 2007), Purwakarta (Miharja 2008), and Magelang (Widiyani *et al*. 2011). All populations are of Mongoloid race, so enviromental factors such SES and human activities had greater influence on body size differentiation than genetic factors. It is a well known fact that the affluent populations enjoy greater physical growth than poor ones (Delemarre-van de Waal 1993; Shen *et al*. 1996; Mueller & Smith 1999; Rahmawati *et al*. 2004; Artaria & Henneberg 2007). The samples taken from Yogyakarta, Karawang, and Magelang came from urban populations with higher SES than Sasak Children; hence we can assume they had better nutrition and living conditions. On the other hand, the samples taken from Purwakarta and Bantul came from rural populations with SES relatively similar to that of Sasak Children. In all of our study populations of Sasak children, the monthly income of their parents was unstable and lower than the regional minimum wage of NTB. In general, the Sasak children are shorter and lighter than children of the same age in urban populations, and the Sasaks are relatively similar in size to the children in rural populations in Java (Figures 8 & 9). This agrees with other studies that show that growth constraint of body size is strongly associated with poverty (Julia *et al*. 2004; Water *et al*. 2004).

In conclusion, the children in low altitude population were taller and heavier than children at medium and high altitude populations. Until puberty, the children in medium population have similar stature and weight to populations who reside in high altitude areas, but are shorter and lighter thereafter. The differences of height and weight between Sasak populations at different altitudes are statistically significant in girls but not in boys. Family income and parental education exerted more influence to the differentiation than the altitude factor.

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