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Original research article

Growth Pattern of Body Size in Baduy People

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ABSTRACT

Understanding body size growth pattern is one of the best ways to find out biological variation in phenotypic plasticity, health and nutritional statuses, and quality of life. Optimum environment and better nutrition are associated with rapid growth, tall stature, and early puberty. However, poor living condition impacts every stage of development, which results in variation in growth rates, growth periods, and body sizes across populations. Baduy is one of traditional populations who inhabit mountainous area in Kanekes Village, Lebak Regency, Banten Province, Indonesia. The traditional obligatory duties and taboos resulted in genetic, geographic, and cultural isolations. This leads to question whether the biocultural condition affects the growth pattern of their body size. We measured the body height, weight, and mass index of 340 girls and 239 boys aged 4–30 years sampled from 39 of 61 hamlets using cross-sectional method. We found that Baduy people had prolonged growth resulting in small body size because of slow rate and low spurt. This might be a selection to save body maintenance costs in biocultural condition with poor nutrition and high physical activity.

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1. Introduction

Understanding body size growth pattern is one of the best ways to find out biological variation in phenotypic plasticity, health and nutritional statuses, and quality of life (Bogin 1999; Eveleth and Tanners 1990; Migliano *et al.* 2007; Rogol *et al.* 2000; Urlacher *et al.* 2016; Walker *et al.* 2006a). Children living in favorable environment and better nutrition grow faster, taller, and get earlier puberty compared with those living in poor condition (Bogin 1999; Eveleth and Tanners 1990; Walker *et al.* 2006a). Poor living condition in many unfortunate areas of the world impacts every stage of development, which result in variation in growth rates, growth periods, and body sizes across population (Kramer and Greaves 2010; Walker *et al.* 2006a). In several small-scale populations, slow growth, small adult size, and late sexual maturity are associated with low energy availability and environmental constraints (Frisch 1975; Gurven and Walker 2006; Migliano *et al.* 2007; Walker *et al.* 2006a; Walker *et al.* 2006b). In contrast, mortality risk (i.e. parasitic and infectious diseases) leads to faster growth and earlier reproductive development, where children and juvenile reached larger size as a survival mechanism, but got small size in

adult (Kramer and Greaves 2010; Migliano *et al.* 2007; Perry and Dominy 2009; Walker *et al.* 2006a).

In Indonesia, there are several indigenous populations that are local and less or not involved in the network of social services, economics, and politics. Baduy is one of those traditional populations who inhabit isolated area (5100 ha) of mountainous rainforest in Kanekes Village, Lebak Regency, Banten Province, Indonesia (Ichwandi and Shinohara 2007; Iskandar and Ellen 1999). The traditions of Baduy are coded in Sundanese religious belief called *Sunda Wiwitan*, which determines social and cultural conducts and daily obligatory duties that relate to Swidden agriculture (Ichwandi and Shinohara 2007; Wessing and Barendregt 2005). Marriage of Baduy people follows endogamy system (Lubis 2009). If they marry people from outside, they must go out off Baduy area. They implement the strict monogamous system (Lubis 2009). In farming processes, Baduy uses traditional technology for protection and maintenance of their land. They make their own mechanical tools and prohibit modern technology and its product such as synthetic fertilizers and pesticides (Iskandar and Ellen 1999). The prohibition extends to all external technology including electricity, electronic equipment, transportation device (even footwear), and modern household utensils. Because of transportation taboo, their settlements can only be reached by walking (Erwinantu 2012; Hasman and Reis 2012; Kurnia and Sihabudin 2010).

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The traditional obligatory duties and taboos of Baduy results in geographic and cultural isolations, which effectively put barriers to education, socioeconomic exchanges, and good quality nutrition. Furthermore, the endogamy system of Baduy would lead to genetic distinctness because of the absence of migration. Those unique bioculture shape the growth trajectory of Baduy people. Here, we report body growth of Baduy people characterized by slow growth rate, small adult size, and prolonged growth.

2. Materials and Methods

2.1. Subject

Baduy growth pattern is described using cross-sectional method. Before taking the data, subject signed informed consent letter. This research had been approved by Office of National Unity, Politics and Public Protection of Lebak Regency (permit letter No. 300/246-Kesbang Pol & Linmas/VI/2013) and abode by the Baduy customs outlined by Head of Kanekes Village.

The data were collected from 39 of 61 hamlets in Kanekes Village that was conducted in 2011 and 2014. Subjects were 340 girls and 239 boys aged 4–30 years. Pregnant women were excluded in this research.

Most subjects do not have birth date records. We relayed the information of subject's age or birth date to an important event or ceremony in their calendar. Parent, siblings, and other community members assisted to recall young children's ages. If the information was age (in year) and interview was at 1 January to 30 June, the birthdate was assigned to 1 January of the estimated year; if the interview was at 1 July to 31 December, the birthdate was assigned to 2 July (regular year) or 1 July (leap year) (cf. [Freedman et al. 2002](#)). In case the information was the year born, it was converted to 1 July of the year ([Freedman et al. 2002](#)).

2.2. Body size measurement

Measurement of body size consists of body height (BH) and body weight (BW) and their derivate body mass index (BMI). BH was measured to the nearest 1 mm by using a stadiometer (*Seca*). BW was measured to the nearest 100 g in normal daily clothing without shoes. BMI was calculated by using the formula: $BMI (kg/m^2) = BW (kg)/BH (m^2)$ ([WHO 1995](#)).

2.3. Data analysis

Generalized additive models for location, scale and shape ([Stasionopoulos and Rigby 2007](#)) model was used to smooth age-related change of BH, BW, and BMI and predict the percentiles 2.3, 3, 5, 10, 25, 50, 75, 85, 90, 95, 97, and 97.7 ([Kuczmarski et al. 2002](#)) of each yearly cohort. In addition, annual velocities of body size were calculated as yearly increment from the 50th percentile. Velocity curve was created for each sex by putting the increments at mid-points between consecutive years. The annual velocity was used to identify age at peak velocity and age at velocity reaching zero. We considered the growth reached completion when velocity equals zero. All data were run using R software version 3.3.2 for Mac ([R Development Core Team 2016](#)).

3. Results

3.1. BH

[Figure 1](#) shows BH growth pattern of girls and boys. In early growth at age 4 years, stature of girls (96.3 cm) was slightly shorter than boys (99.8 cm). The statures grew to similar height from age 6 to 14 years; however, growth trajectory of girls started to differentiate from boys at 15 years when girls became shorter. The

maximum growth rate of girls (4.5 cm/year) was lower than boys (5.1 cm/year), and this was reached at 10.5 years, 2 years earlier than boys. After that the growth rate continuously decreasing to zero. Thus, the stature of female (149.4 cm at 21.5 years) was shorter than male (161.4 cm at 23.5 years) when the growths were completed. After the growth completed, there were negative accelerations that might indicate secular trend.

3.2. BW

Growth pattern of BW followed the same pattern as BH, but in different tempo ([Figure 2](#)). At age 4 years, the BW was 12.5 kg and 15.4 kg in girls and boys, respectively. The BW became similar in both sexes from age 7 to 17 years before girls started to be lighter than boys. The maximum growth rate of girls (2.9 kg/year at 13.5 years) was also lower than boys (3.4 kg/year at 14.5 years). BW of female reached 47.7 kg at growth completion (at 25.5 years); whereas in male, the BW still increasing at age 30 years (54.4 kg) and more.

3.3. BMI

We also found BMI in both sexes increased following age with same pattern as BH and BW ([Figure 3](#)). At age 4 years, the BMI of girls (13.8 kg/m²) was smaller than boys (14.9 kg/m²); but at 10 years, they started to be bigger than boys. The maximum growth rate was a bit higher in girls (0.7 kg/m²/year) than boys (0.6 kg/m²/year) and both reached at same age 14.5 years. Until age 30 years, BMI in both of female and male remained increasing and reached 21.8 and 20.9 kg/m², respectively. It is interesting to note that we could not detect when the velocity turned zero.

4. Discussion

Our result showed that the adolescent growth spurt and cessation of Baduy girls occurred earlier than boys. Adolescent growth spurt is linked to puberty so the earlier maturity of girls ([Frisch 1975](#); [Frisch and Revelle 1969](#)) was thought of as necessary to survive and to prepare for pregnancy and lactation, which needs high energy ([Kramer and Greaves 2010](#); [Walker et al. 2006a](#)). In contrast, boys grew longer to reach larger body size that might prove important for competition in getting mate ([Walker et al. 2006a](#)). At the growth cessation, body size of female (BH = 149.4 cm; BW = 47.7 kg) was smaller than male (BH = 161.4; BW = 54.4 kg) because of lower maximum growth rate ([Figures 1 and 2](#)). Interestingly, both sexes of Baduy had prolonged growth pattern into around 25.5 years for female and over 30 years for male because of slow growth rate and low growth spurt ([Figures 1 and 2](#); [Tables 1 and 2](#)).

Compared with contemporary populations, Baduy was shorter and lighter than the children of Bogor urban ([Puspita 2004](#); [Suhartini 2007](#)) and Bantul rural ([Rahmawati et al. 2004](#)) areas in Indonesia and other countries such as America ([Kuczmarski et al. 2002](#)) and Japan ([Kagawa and Hills 2011](#)) ([Figure 4](#)). Baduy had harsh living condition with more physical activity and limited access to good nutritional food than Bogor, Bantul, America, and Japan populations. The body size of Baduy was similar with other small-scale societies in several countries ([Figure 5](#)), which had poor living condition. The prolonged subadult period and small body size during growth period might be a selection to save body maintenance costs ([Gurven and Walker 2006](#); [Walker et al. 2006b](#)). In our observation, nutrition intake of Baduy people was poor as most of Baduy eat rice and salted fish almost every day and only sometimes they consume available local vegetable and fruits. Moreover, daily obligatory duties of Baduy tradition related to Swidden farming using traditional technology in hilly area with average slope of 49.1% demanded high physical activity ([Ichwandi and Shinohara](#)

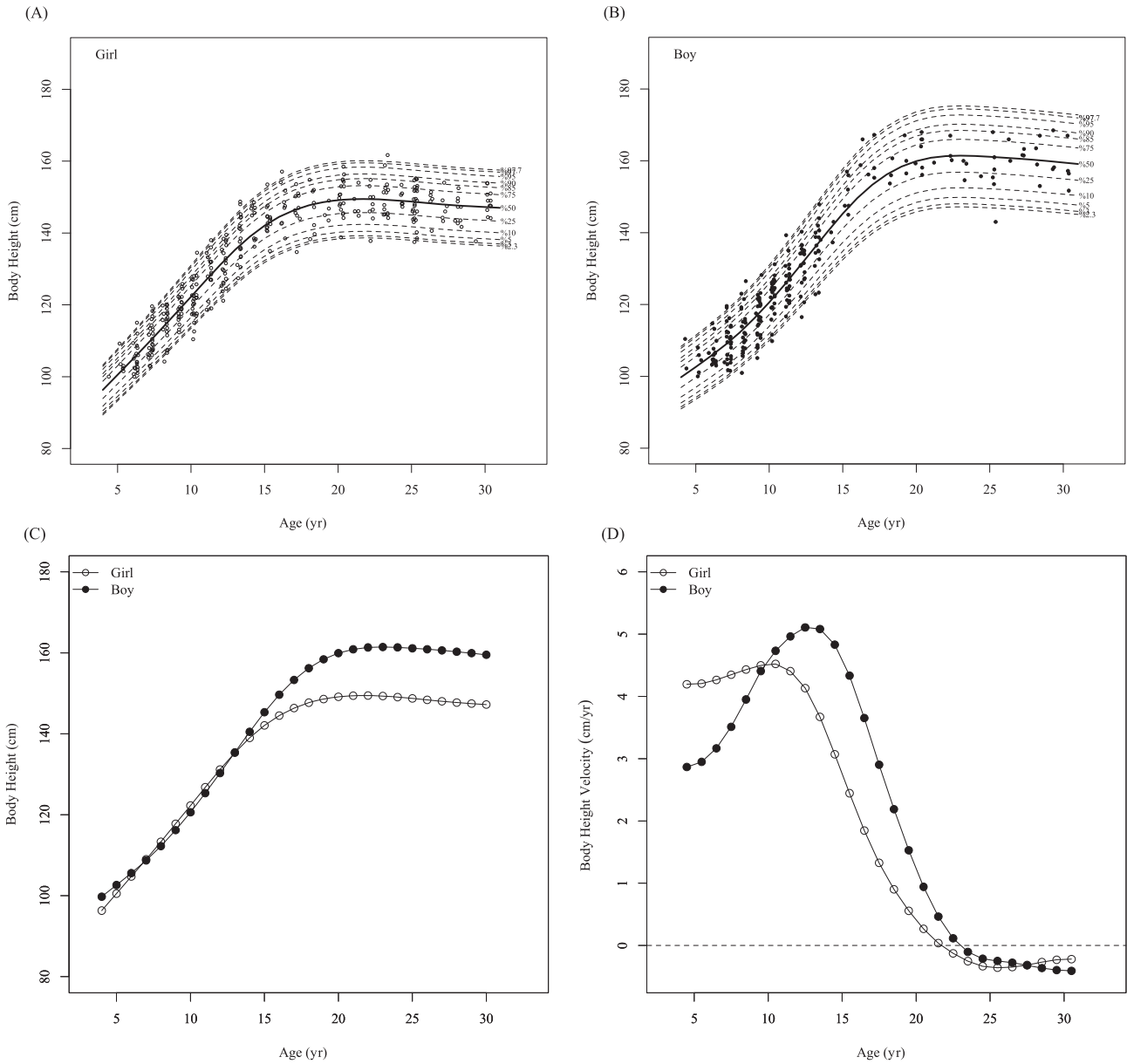


Figure 1. Growth of body height of Baduy people aged 4–30 years. (A) Girl, (B) boy, (C) growth pattern from the 50th percentile, and (D) growth velocity. Bold line is the 50th percentile.

2007; Iskandar and Ellen 1999; Iskandar and Iskandar 2015). Average energy intake of an adult Baduy male at 2517 kcal was lower than energy he expended at 2935 kcal per day (Hestiwati 1983). Consequently, energy expenditure might not balance with calorie consumed. Furthermore, Baduy people work in their Swidden field for around 8 months in a year from planting to harvesting of Swidden rice (Ichwandi and Shinohara 2007; Iskandar and Iskandar 2015). Baduy children also start to learn about Swidden farming at age 10 years, therefore the biocultural condition related to poor nutrition and high physical activity were experienced early on in their growing period. This condition lead to slow body growth rate with low spurt resulting in the characteristics that was small in size and late in full-grown age.

In Pygmy population, small body size (average stature of adult male <155 cm, see Figure 5) was found to relate to saving on body maintenance costs, mortality risk, and early onset of reproduction (Kramer and Greaves 2010; Migliano *et al.* 2007; Perry and Dominy

2009; Walker *et al.* 2006a). Juvenile mortality risks are the main force behind faster and earlier growth that lead to their small adult body size (Walker *et al.* 2006a). The large body size at young ages may be important for struggling mortality risk (Migliano *et al.* 2007). In Kanekes village, based on census data in 2011, total births consisted of 170 individuals with four died before 1 year, resulted in 24 (=4/166 × 1000) infant mortality rate (IMR). In 2012, total births consisted of 177 individuals with five individuals died before 1 year, resulted in 33 IMR (Office of Health, Lebak Regency, unpub.). Compared with national level of Indonesia with IMR at 32 individuals per 1000 births in 2012 (Kemenkes RI 2016), Baduy people had relatively low or similar infant mortality pressure. There is no data on juvenile mortality; however, the general condition of low infant mortality may continue to juvenile age in contrast to high mortality from infant through juvenile that had been reported in the pygmy Agta population (Headland 1989). We may conclude that in contrast to Pygmy population we could not find evidence

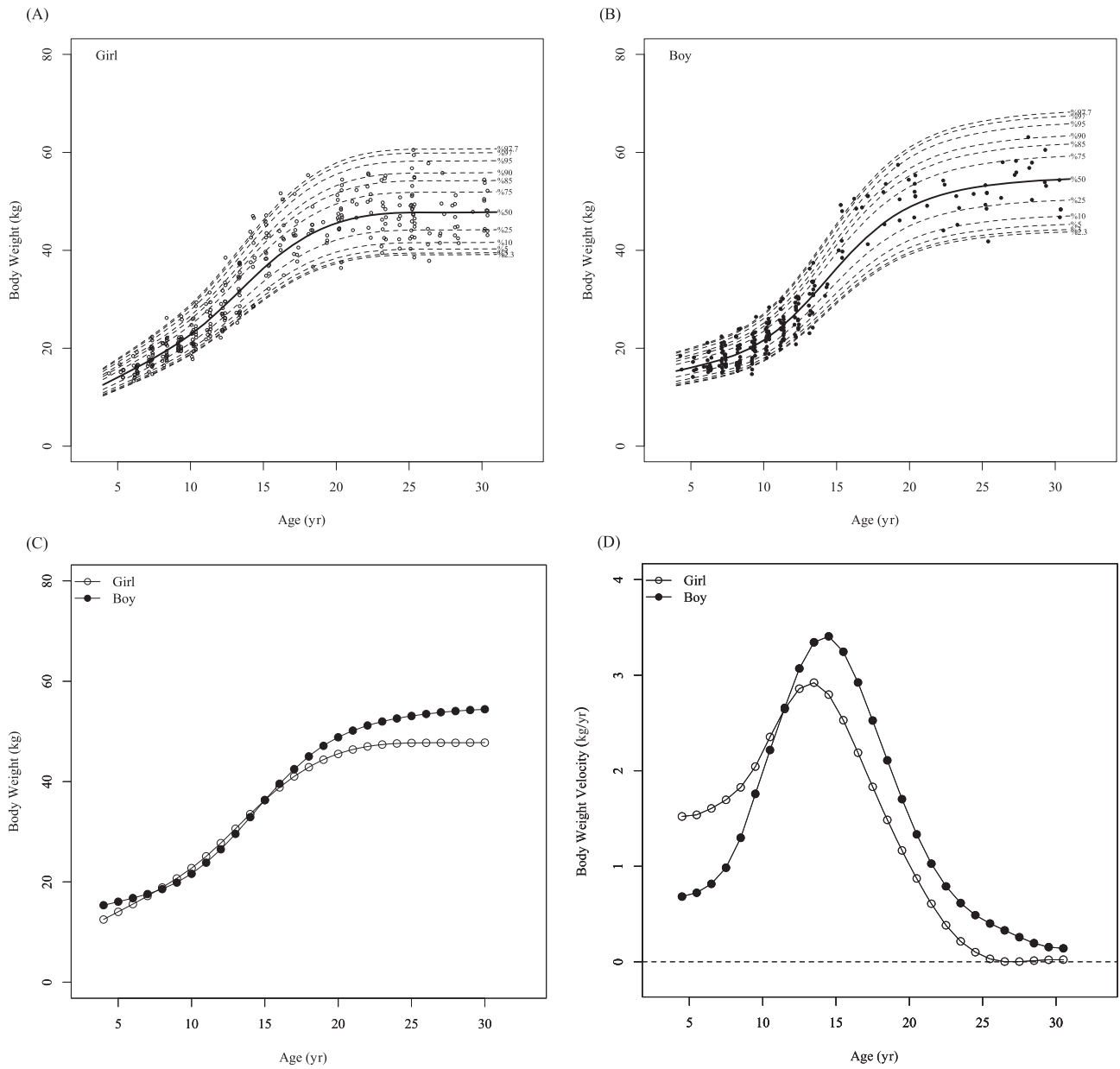


Figure 2. Growth of body weight of Baduy people aged 4–30 years. (A) Girl, (B) boy, (C) growth pattern from the 50th percentile, and (D) growth velocity. Bold line is the 50th percentile.

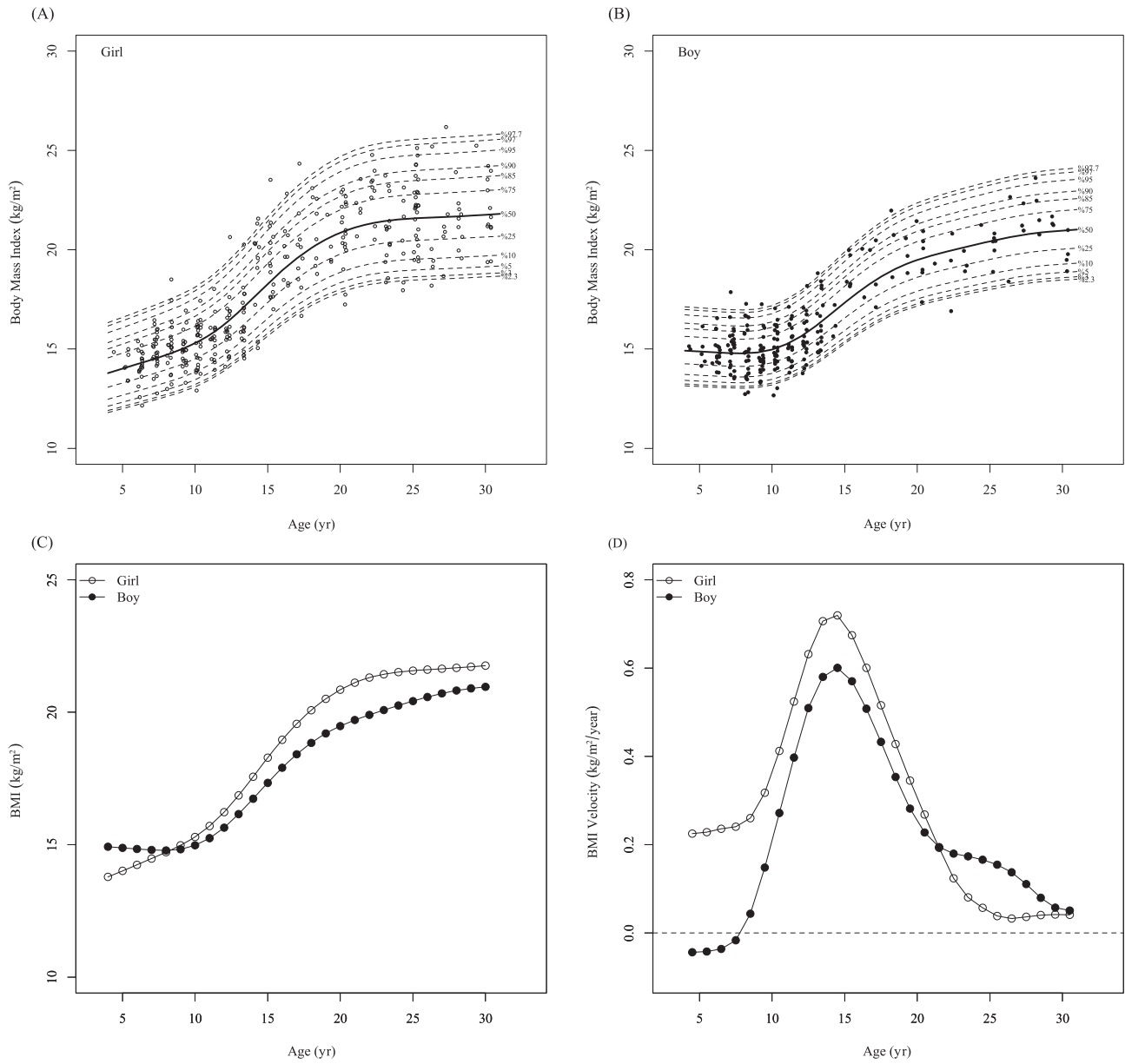


Figure 3. Growth of body mass index of Baduy people aged 4–30 years. (A) Girl, (B) boy, (C) growth pattern from the 50th percentile, and (D) growth velocity. BMI, body mass index (see text). Bold line is the 50th percentile.

Table 1. Comparison of growth pattern of body height in some populations

Population	Girls			Boys		
	APV		Age at growth completion (yr)	APV		Age at growth completion (yr)
	Magnitude (cm/yr)	Age (yr)		Magnitude (cm/yr)	Age (yr)	
Baduy	4.5	10.5	21.5	5.1	12.5	23.5
Magelang	6.0	9.5	17.5	—	—	—
Japan	6.8	10.5	15.5	7.6	16.5	16.5
America	7.2	10.5	16.5	8.2	18.5	18.5

APV, age at peak velocity.

Sources: Magelang (Widiyani *et al.* 2011), Japan (Kagawa and Hills 2011), and America (Kuczmarski *et al.* 2002).

Table 2. Comparison of growth pattern of body weight in some populations

Population	Girls			Boys		
	APV		Age at growth completion (yr)	APV		Age at growth completion (yr)
	Magnitude (kg/yr)	Age (yr)		Magnitude (kg/yr)	Age (yr)	
Baduy	2.9	13.5	25.5	3.4	14.5	>30.0
Magelang	4.2	11.5	19.5	—	—	—
Japan	5.2	10.5	16.5	6.0	11.5	—
America	5.4	11.5	18.5	7.1	13.5	18.5

APV, age at peak velocity.

Sources: Magelang (Widiyani et al. 2011), Japan (Kagawa and Hills 2011), and America (Kuczmarski et al. 2002).

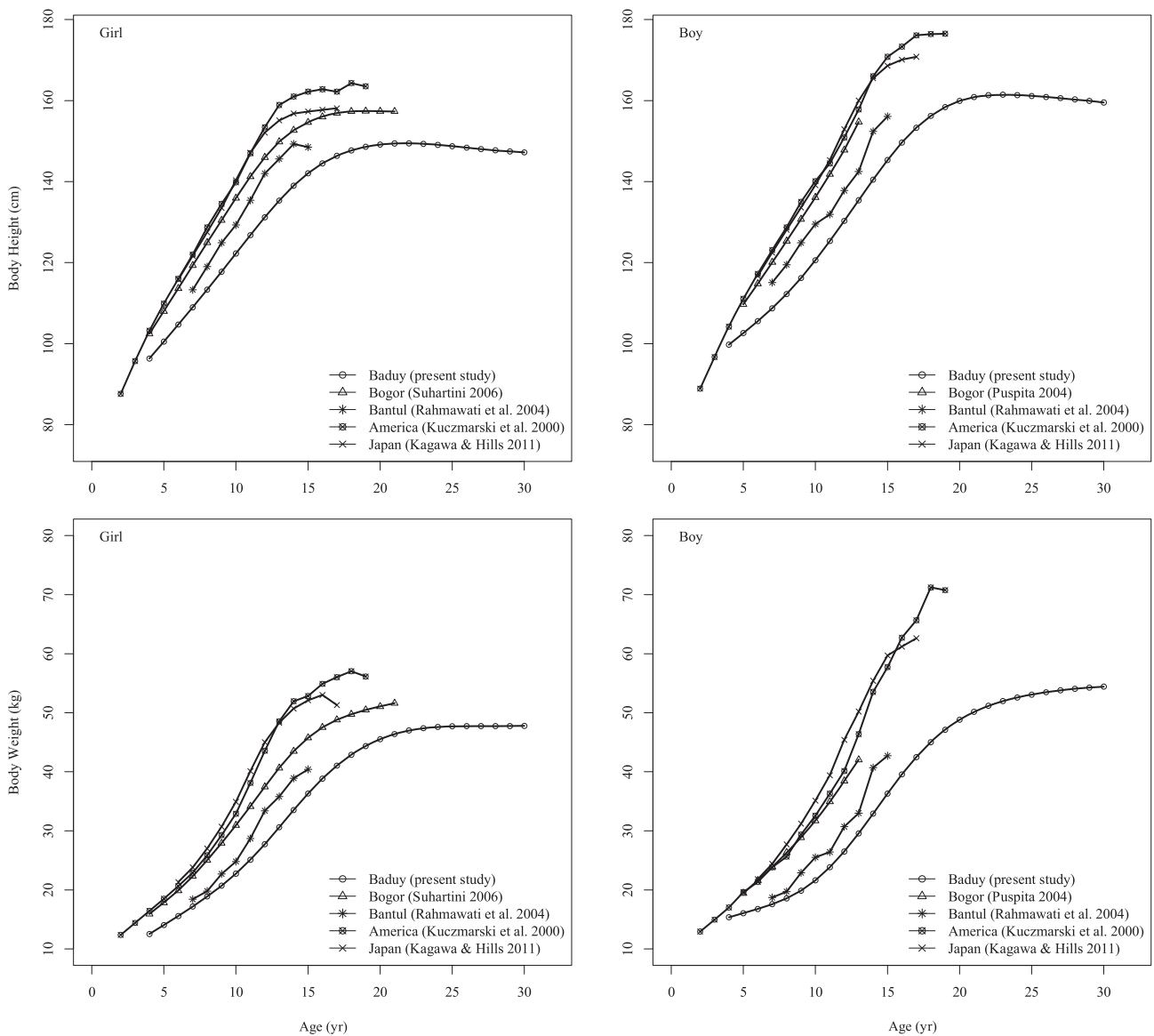


Figure 4. Comparison of body height and weight of Baduy people with other populations from Indonesia and other countries.

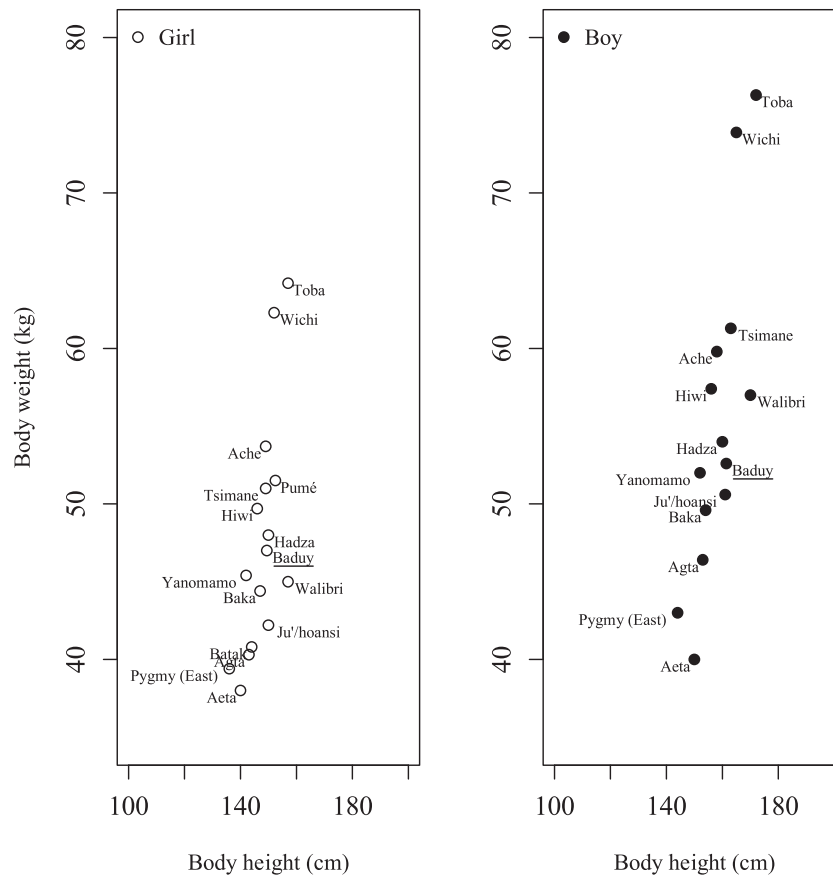


Figure 5. Comparison of adult body size between Baduy people and other small-scale populations in several countries (sources for non-Baduy: Pumé from [Kramer and Greaves 2010](#), others from [Walker et al. 2006a](#)).

that the prolonged growth and small body size of Baduy people were related to mortality pressure, instead we observed that poor nutritional food and high physical activity shaped the life history.

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Conflict of interest

The authors declare that there is no conflict of interest to declare.

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