学 位 論 文

Ecology of Baka hunter-gatherers' children in southeast Cameroon.

－nutritional status, physical activities, and daily behaviors－

カメルーン南東部に居住するピグミー系狩猟採集民の子どもにおける生態学的研究
－栄養状態・身体活動・生活行動－

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ABSTRACT

[Background]

Hunter-gatherer societies are characterized by subsistence based on gaining wild food resources and no domestication of plants or animals, and also described as “immediate-return” culture. They traditionally lived in a high mobility lifestyle, and their subsistence conditions are easily affected from ecological, social, and political factors. Partially unstable hunter-gatherer subsistence world makes requirement of returning on the individual investment rapidly, and storing future consumption lesser; hence continuous and certain amount of daily food acquisition are needed. Children in terms of their physical and psychological development, have higher risks from, and vulnerability to, environmental or social hazards than do adults. Contribution to subsistence by hunter-gatherers’ children were seldom described since they were rarely regarded as prospective foragers until fully matured. However, because nearest a half of hunter-gatherer population were consisted by children, it is hard to maintain their subsistence economy by depend on only adults; thereby the self-support among children are considered to be necessary and should be existed.

The current study explored the ecological system among hunter-gatherers’ children who are living in central African rainforest area from the aspects of nutritional status, physical activities, and daily behaviors.

[Field research]

During FY 2010 to FY 2014, fieldwork including demographic surveys, anthropometric measurements, GPS tracking, acceleration monitoring, and daily behavior observations were performed on Baka hunter-gatherer’s children in southeast Cameroon. The Baka are one of the groups of pygmy hunter-gatherers, and relatively semi-sedentarized. The surveys were conducted in both sedentarized village camps along trunk load and foraging camps in rainforest.

[Results and Discussion]

Demographic characteristics obtained from longitudinal census surveys and retrospective family tree interviews showed the comparable level of fertility and trend of natural population increasing among Baka population. The mean value of completed parity (5.03 ± 3.05) obtained from 295 ancient Baka females appeared in reconstructed family tree was moderate among the modern hunter-gatherer societies. Daughter-mother ratios as an indicator of population increasing rates were approximately 2.5–3.0, which also indicated the high potential of natural population growth.

The height and weight growth curves of Baka children obtained from cross-sectional measurements were generally below 3rd percentiles of U.S. reference. The mean values of Z-scores of height and weight for their ages (HAZ and WAZ) were also lower (below –3.0 and –2.0, respectively); over 90% of Baka children were suspected in chronic malnutrition. However, two z-scores (WHZ and AMAHZ) which standardized the body weight and arm muscle area by their height indicated that Baka children's body weight and arm muscle amount were comparable to those of U.S. children in same height. In addition, 15-years of longitudinal survey at one village found the child growth tempo was unchanged and similar to developed countries' children. From these results, the nutritional status of current Baka hunter-gatherer was considered to be well-nourished.

From accelerator/pedometer monitoring in sedentarized village camps, extremely high level of daily physical activities among Baka children were revealed. The mean values of Physical activity level (PAL) exceeded 2.0, and daily step counts were approximately 25,000–30,000 per day. As their age increased, Baka children tended to go out from their villages or camps, and expand their activity areas steadily. Older children (10–18 years old) often visited to other villages and stayed in a forest 2–3 hours for everyday; however, even in their early childhood (3–6 years old), they stayed meanly an hour in forest. Step counts were strongly associated to daily travel distance, activity radius, and PAL; hence, it was considered that physical activities of Baka children were fundamentally generated from walking.

From direct observations of daily time allocation in the foraging forest camps, it was revealed that Baka children tended to spend considerable length of daily time to food procurement activities even in the childhood. Daily total time of hunting, fishing, and gathering by children (142–227 min/day) were considered to be comparable to Baka adults usually spent. As their age increased, time allocated for "playing" got decreased (meanly from 30 to 3 min/day), and children become concern food procurement activities autonomously and avidly. Although the numbers of population and total consumption-days were greater in children than adults (410 person-days and 156 person-days), total amounts and variation of forest products brought back to camp were so much greater in adults. However, Baka children tended to avoid wholly rely on adults to gain daily foods. They are eager to acquire forest food products and tried to meet their energy requirement by themselves.

[Conclusion]

Baka children were considered to be generally healthy and well-being. In their small ecological world, the relationship among nutritional status, physical activity and daily behavior, and nutritional intake was considered to be circulated steadily and stimulatingly.

I. INTRODUCTION

Children in terms of their physical and psychological development have higher risks from, and vulnerability to, environmental or social hazards than do adults (Engle et al., 1996). Disease infection, shortage of food/nutrient intake, high social stress, and low socioeconomic status are known as typical factors which influence to child health status (Bradley & Corwyn, 2002; Cole, 2003; Heltberg, 2009). These effects from ambient environment often produce biological variation as growth pattern, physical characteristics, pubertal timing, and final height, and likewise behavioral variation as daily physical activity and behavior pattern among children (Froment, 2014; Steckel, 1995; Tanner, 1992). For these reasons, various parameters obtained from child associated surveys are often used as indicators to assess the health status of an entire population (Bogin, 1999; WHO, 1986).

Hunter-gatherer societies which maintain original subsistence activities are characterized by subsistence based on gaining wild food resources and no domestication of plants or animals, and also described as “immediate-return” culture (Woodburn, 1982). They traditionally lived in a high mobility lifestyle, and their subsistence conditions are easily affected from ecological, social, and political factors (Hewlett & Lamb, 2005). Partially unstable hunter-gatherer subsistence world makes requirement of returning on the individual investment rapidly, and storing future storing consumption lesser; hence continuous and certain amount of daily food acquisition are needed.

Children living in the societies in developing countries or traditional agricultural

societies are regularly involved in domestic tasks in their families and they somewhat contributed to household works or subsistence work (Kramer, 2005; Munroe et al., 1984). However, contribution to subsistence by hunter-gatherers' children were not described frequently since they were rarely regarded as a prospective forager until fully matured (Hawkes et al., 1995; Kaplan et al., 2000). In hunter-gatherer society, due to their emphasized egalitarianism and individualism like *laissez-faire* policy, children are rarely forced to take responsibility for their subsistence work. In spite of rich notes about adult hunter-gatherers' food procurement activities, children often ignored in the description of subsistence activities (Hirshfeld, 2002; Lancy, 2012), and it is also mentioned that adults almost never expected the fruit of food contribution from children (Kamei, 2005). However, children consist nearest a half of members in many hunter-gatherer populations (Hewlett, 2014; Howell, 1979). Even though adult hunter-gatherers could brought back certain amount of wild food by daily foraging, it is considered to be hard to maintain their subsistence economy by wholly depend on only adults; thereby the self-support among forager children are considered to be necessary and should be existed.

Pygmy hunter-gatherers in central African rainforest.

Pygmy hunter-gatherers, who are called as "Forest people", are thought to be original inhabitants of central African rainforest (Turnbull, 1962). Pygmy hunter-gatherers are ecologically divided into major two groups such as east group (Efe, Mbuti, and Twa) inhabit

Ituri forest in east-side of Democratic Republic of Congo, and west group (Baka and Aka) living in northwestern Congo Basin (Bahuchet, 2014). Several diversities are known between the groups of Pygmy societies; however, there are common cultural characteristics as central African rainforest foragers were considered to be appeared (Hewlett, 1996; Tsuru, 1998).

The remarkable physical characteristics among pygmy hunter-gatherers which are extremely short stature had been attracting the attention of anthropologists for many centuries (Diamond, 1991). So-called “Pygmy” populations are well-defined by cultural perspectives such as forest-depended lifestyle, relationship to farmers, and ritual activities associated with elephant hunting (Hewlett, 1996). It is difficult to establish biological definitions of them (Cavalli-Sforza, 1986); however, the review of anthropometric surveys mentioned the mean adult heights of pygmy hunter-gatherers are generally shorter than 160 cm in male and 150 cm in female (Froment, 2014). Certainly, they are one of the shortest populations with normal body shape in the world (Shea & Bailey, 1996; Yamauchi et al., 2000); in addition, their mean stature was considered to be unchanged for over decades (Hagino et al., 2014; Travaglino et al., 2011).

Various evolutionary hypotheses, such as: adaptation to uneasy mobile forest environment, to low food availability, to hot and humid equatorial rainforest climate, to life history trade-offs with high mortality were proposed and verified to explain this unique phenotype (Bailey et al., 1989; Cavalli-Sforza, 1986; Migliano et al., 2007; Perry & Dominy, 2009; Sato et al., 2012). Recent researches from genetics view were also carried out mainly in

northwestern Congo Basin, and focused on the mate choice and admixture with neighbor Bantu farmers (Becker et al., 2011; Becker et al., 2012; Romero et al., 2013; Verdu et al., 2009). However, the origin of the phenotype of short stature was not clearly proved.

In this trend, numerous anthropometric studies on children have been performed in an attempt to understand their growth pattern and nutritional status of pygmy hunter-gatherers. The paper of van de Koppel & Hewlett (1986) suggested that the absence of an adolescent growth spurt among Aka children from mixed-longitudinal survey with results from some laboratorial studies focused on the mechanism of growth hormone, growth hormone receptor, and insulin-like growth factor I (Becker et al., 2013; Rimoin et al. 1969, Merimee et al. 1972, 1987). Bailey (1991b) obtained longitudinal exact values for height and weight of Efe children in Ituri forest with actual ages of 0 – 5 years which were smaller and lighter compared to neighbor Lese farmers' children. Our cross-sectional survey and mathematical model applying study of Baka children's height growth found the weak presence of adolescent growth spurt, slower growth rate until juvenile, and ordinary timing of growth spurt's initiation (Hagino et al., 2011, 2013; Yamauchi & Hagino, 2014).

The Baka hunter-gatherer children and their ecology

The Baka are one of the groups of pygmy hunter-gatherers, and their habitats are extending over the Republic of Cameroon, the Gabon, the Central African Republic, and the Republic of Congo. Their total population has been estimated to be 25,000 – 40,000 (Figure.

1; Althabe, 1962; Joiris, 1998; Vallois & Marquer, 1976). Since the mid-20th century, the sedentarization and agriculturization policies for Baka communities were promoted, and almost Baka villages currently form alongside trunk roads (Figures. 2-3; Joiris, 1998; Sato, 1992). Traditionally, their camp size were regarded approximately 30 – 40 (Hagino et al., 2014; Hewlett, 2014); however, the upper limit of village camp size are increasing up to 200 – 300. Many Baka have their own small cultivated patch of land to grow bananas, cassavas, and maize as staple foods, and sometimes cultivate cacao and some vegetables (e.g. tomatoes, onions, and cabbage) as cash crops (Kitanishi, 2006; Oishi, 2012). However, they still retain their traditional hunting and gathering lifestyle and enter the rainforest for long-term foraging trips that aim at game or nut collection in accordance with the seasons (Hattori, 2014; Yasuoka, 2006), and their lives still strongly depend on the forest.

The Central African tropical rainforest is an area which was indicated to be difficult to lead a nomadic hunting and gathering life due to its low food availability against its huge biomasses (Bailey & Headland, 1991; Hart & Hart, 1986; Headland, 1987). The abundance and availability of wild yam tubers and yam-like plants were considered to be caloric sufficient for hunter-gatherer subsistence in the western Congo Basin (Bahuchet et al., 1991; Sato, 2001, 2006; Yasuoka, 2013), additionally, many studies described that sufficient protein contained food resources could be obtained through a certain period of hunting camp conducted by pygmy hunter-gatherers (Ichikawa, 1982; Sato et al., 2012; Yasuoka, 2006). Most of these wild forest food resources were mainly obtained by adult groups, and the details

of hunting activities by Pygmy children were rarely described.

Only few studies (10 – 15% of whole pygmy hunter-gatherers studies) focused on their children (Hewlett, 2014). These studies were mainly focused on two aspects. The one is biological aspects examined child growth pattern and health condition, and the other is social aspects with descriptive notes about child playing or leaning (Terashima, 2011, 2012, 2013, 2014). There was no study quantitatively examined the daily life of Pygmy children, and biological ecology of pygmy hunter-gatherers' children were rarely clearly described.

The outline of study

In this thesis, the author described the ecological system among Baka hunter-gatherers' children living in rainforest area of southeast Cameroon from the aspects of nutritional status, physical activities, and daily behaviors.

Chapter II investigates demographic characteristics as basic information of current Baka hunter-gatherer society in Republic of Cameroon. Chapter III analyzes the nutritional status of Baka children and adults from the perspectives of child physical development, body size and composition. In the former chapter [Chapter III-1], the nutritional status was widely assessed using international clinical reference within a large sampled cross-sectional survey. The latter chapter [Chapter III-2] focused on the secular trend of the nutritional status among one village inhabitants by generational and social effects. Chapter IV describes the physical activities and daily behaviors among Baka children in sedentary village camp and foraging

camp. The survey of Chapter IV-1 was performed in sedentary village camp. The physical activity level and daily time-space using were observed by using GPS tracking/acceleration monitoring methods. Chapter IV-2 shows the child behaviors and food acquisition activities in the forest camp.

The ethics of study

The study was approved by the ethics committee of the Graduate School of Health Sciences, Hokkaido University (11–13). Participation in the study was voluntary using explanations of the study for participants and care persons using local languages. Consent was obtained from the children and their parents or the chiefs of villages.

II. POPULATION STRUCURE, DYNAMICS AND FERTILITY

METHODS

Study area and Data collecting

The research site, four Baka villages were located nearby a central of city of Lomié, Haut-Nyong Department, East Province of Cameroon. These four villages were within the range of about 5 km radius. Three villages were along the trunk road, and another one is located in forest which passed about 3 km of narrow bush road. These villages were considered to be as one group with following reasons: 1) the neighboring Baka villages outside of these four villages were apart 10 – 30 km, 2) there were several marital and kinship relation among these villages, and 3) three villages were belonged to a canton. All villages were contained only Baka residents.

Field investigations were conducted during dry seasons, February–March 2012, February 2013, and February–March 2014. Three times of longitudinal census data which identified name, sex, age class, clan, birthplace, and marital and birth history of all living members in each village were collected. In 2013 and 2014 surveys, the information about newborn and death during a past year were also obtained. The ages of the inhabitants were estimated by following information: 1) birth reordering within the whole village (for small population sized village) or divisions in the village (for large population sized village), 2) matching their birth date with local or national events, and 3) inscribed birth year on the identify card which issued by government.

The genealogical data were also collected by means of interviews with village inhabitants in question and with aged or familial person. Interviews were performed 66 females who had married and lived in target villages at August 2013. The subjects of this study were females appeared in the reconstructed pedigree who had married and died or, if still living, had passed their reproductive ages. The personal information which included name, sex, clan, and marital, parent-child- and sibling relations (in biological term) was identified to the subjects, her sibling, mother, and grandmother, if possible. Because of their traditional nomadic lifestyle, the participants sometimes be in ignorance or failed to recall of the information about ancient people, their cousins, or even their siblings. In this study, the family tree data of their mother's side were only obtained. Finally, 295 females' personal data was obtained.

Using the number of *de facto* population, birth, and death obtained from census data, two demographic indices of crude birth rate (CBR) and crude death rate (CDR) which determined as the number of live birth and death per 1,000 of the population per year were calculated. The number of migrated population was also obtained, thus the trends of natural and social increment were also estimated. To estimate participants' fertility, the mean completed parity was calculated from the 295 females' data appeared in pedigree. This index is the mean value of the number of live born who were born married mother group, and known to be alternative to TFR (total fertility rate) (Nakazawa & Ohtsuka, 1997). Mean completed parity was compared with international statistics and previous demographic or

anthropological studies.

As the indicator measuring natural population increase and inter-generational difference of fertility, daughter-mother ratio (DMR) were calculated. DMR is the average number of daughters who were born female group of married women during the lifetimes and who survived to marry (Ohtsuka, 1990). DMR can be treated as a substitute of net reproduction rate (R_0), and the rate of natural increase, or Lotka rate (P), is calculated from the following formula:

$$P = \sqrt[y]{R_0} - 1$$

where y is the mean age at childbearing (Pressat, 1972). Age at childbearing were temporally given at 20 and 25 years. Several qualifications as fixed pattern of age-specific fertility and mortality, and fixed marital age over the generations are needed to apply DMR; however, because of the difficulty to provide sufficient evidence for some decades by the lack of former description, these factors were postulated from author's judgment in this study.

Judgment of completion of reproduction was according to Ohtsuka (1990) definition based on following two criteria. The first was the lapse of approximately seven or more years after her last delivery. The ages of their last child were estimated by birth reordering for living children or interviewing and comparing other children who were close in age for died children. For sterile and seldom-pregnant women, estimated the age of the female by comparison with her sibling and/or consanguine. Among the deceased women, only those whose parents and sibling could be certainly ascertained were included.

295 females from genealogical dataset were categorized into four generational groups: (A) not all female offspring have married; (B) All female offspring have married; (C) all female offspring have completed reproduction; (D) All female offspring of all female offspring have married. It is naturally assumed that the mean age interval between these groups is 20-25 years.

RESULTS

Demographic characteristics and population dynamics

Table 1 demonstrates the basic demographic characteristics of the subjects. The number of *de facto* population, number of birth and death, crude birth rate, crude death rate, number of natural increase, and number of social increase were contained. During the two years of research periods, the numbers of birth exceeded the number of death, and number of population was naturally increased. However, the number of inhabitants was socially decreased, thus the total numbers of population were decreased consecutively in these three years. Figure 1 shows the population structure in the first year (February–March 2012) of target area. The number of population was 594 (including 314 males and 280 females). Sex ratio (male / female) was 1.12. The median age of all population was calculated at 19.7 years old, which was similar to 19.0 years old obtained as national statistics of Republic of Cameroon (UN Secretariat, 2011). Male's median age (18.6) was lower than female's (20.9). The percentage of under 15 years old was 41.8%.

Fertility and estimated potential of population increase

Figure 2 demonstrate the percent of distribution of number of children of both sexes from 295 females appeared in reconstructed family tree. The mean parity was 5.03 ± 3.05, and distribution was conformed to neither the normal distribution nor Poisson distribution. The most frequent value was 6 (n = 39, 13.2%), maximum value was 16 (n = 1, 0.3%), and the second largest number was 11 (n = 9, 3.1%). There were 22 females (7.5%) who had married but did not deliver a child. Table 2 shows the number of married females and their offspring who survived to marry. Corresponding Lotka rate and DMR which were the ratio to number of female offspring to number of mothers were also provided. Two levels of Lotka rate were calculated according to each mean age of childbearing, 20 and 25. The DMR of each group was generally exceeded 2.0, and estimated annual population growth rate (*P*) were ranged 0.033 to 0.058.

DISCUSSION

From the population pyramid, the targeted Baka population was considered to be relatively young, and there were about a half population who defined as children in terms of their ages. The percentage of young population (< 15 years old) in these villages (41.8%) was lower than the value previously shown in Baka society (53.7%. Vallois & Marquer, 1976); however, was ranged in four (Bakola, Efe, Mbtui, Aka, and Baka) pygmy hunter-gatherers' societies (Froment, 2014; Hewlett, 1996) and similar to that of statistics of Cameroon (40%. UN

Secretariat, 2011). The number of elder people was also low: only 1.7 % of subjects were older than 65 years old. Froment (2014) reported that the percentage of elderly people (65 < years old) in Bantu population were 10.1 % and so much greater than that of Bakola population (2.1 %).

Table 3 contains the comparison of fertility among modern hunter-gatherer populations (Bentley et al., 1993; Cavalli-Sforza, 1986; Goodman et al., 1985; Hill & Hurtado, 1996; Hewlett, 1991; Hewlett, 1996; Howell, 1979). The fertility of present Baka population was middle-ranged in those of some pygmy hunter-gatherer populations. The TFR among foragers and forager-horticulturist were ranged 3.6 – 7.2, and the mean value of TFRs was 5.5 (Bentley et al., 1993). Because of the difference of robustness, mean completed parity and TFR were not directly comparable (Nazakawa & Ohtsuka, 1997); however, it could be concluded that Baka women had moderate level of fertility. Hewlett (1996) described that Dodd (1979) noted that 4.5% of Baka married women living in Lomié are married to Bantu agriculturist population while Bantu men expect relatively higher fertility among Baka women than Bantu women. Vallois & Marquer (1976) described in their demographic study near Lomié area in the 1940s, the intermarriage between Baka and Bantu were rare. Similarly in our study, the marriage of Bantu men and Baka women were only 1 couple in this area (they divorced during three-years of research period) and Matsuura (2012) also provide low intermarriage rate (2.1%: 3/140) of Baka women and Bantu men. However, there were several cases that Baka women conceived Bantu men's child without marriage in our population.

Many demographic studies describe very low rate (zero percent in most cases) of marriage between Pygmy men and Bantu women (Hewlett, 1996; Matsuura, 2012; Terashima, 1987).

The estimated rate of annual population increase (*P*) was high, which indicate that subjects have the potential to increase their number of population as twice to three times over a generation of 20 – 25 years. Two possibilities were considered to express these values. The first theory is based on that these values of DMR and Lotka rate were true and appropriate. Mean completed parity among three age groups were similar (B: 3.90; C: 3.92; and D: 4.58) and considered to be appropriate comparing mean completed parity of whole subjects (5.03). Crude rates of natural increase in this area (26.9 and 29.8) were also indicated the comparatively high natural population growth trend. In addition, the obtained population pyramid was expansive- or stationary- shaped which suggested the existence of population increase. The infant mortality among pygmy societies summarized by Hewlett (1996) compared were ranged 12.0 – 20.0, slightly higher than whole crude death rate of present Baka population. Sedentarization policy from mid-1900s for Baka people might increase the accessibility to cash economy, public health, and social security; thereby the mortality during infancy and childhood possibly decreased. In a result, survival rate until marriage were considerably high in this area, hence the DMR and estimated population growth rate were relatively high. The other possibility is the overestimation by filed survey setting. In this study, only mother side of family tree was interviewed and reconstructed. On account of calculation, a relatively higher probability of existence of female in the reconstructed family tree might

increase DMR. DMR may decrease about 10 – 30 % when added the family side of pedigree, and the population growth rate can result in 0.02 – 0.04. These expected values were considered to be still high; however, enough explainable.

III. NUTRITIONAL STATUS, ADULT PHYSIQUE AND CHILD GROWTH

III-1. CROSS-SECTIONAL ANTHROPOMETRIC MEARSUREMENTS

METHODS

Cross-sectional surveys were conducted on Baka hunter-gatherers during August-September 2010, and July-September 2011 in 86 Baka semi-settlement villages or forest camp located in the East Province of Republic of Cameroon. A total of 911 children (506 boys, 405 girls) and 760 adults (359 males and 401 females) participated in the study.

The anthropometric measurements, including height, weight, upper arm circumference and skinfold thickness, were performed by author using standard procedures (Weiner & Lounie 1981). Height was measured to the nearest 0.1 cm in participants who could stand using a portable stadiometer (model 213, Seca, Germany). Weight was measured for all participants to the nearest 0.1 kg using a digital scale (model TF-205, TANITA, Japan). Each participant was barefoot and wearing light clothing when weighed. For statistical analysis, 0.3, 0.5, or 1.0 kg for the clothing weight was subtracted from the measured values in accordance with their cloths. Upper arm circumference (UAC) was measured using a glass measure to the nearest 0.1 cm. Skinfold thickness (triceps: TSF and subscapular: SSF) were measured to the nearest 0.2 mm using a Holtain skinfold caliper (Holtain, Briberian, UK). From these data, body mass index (BMI, kg/m^2), upper arm muscle area (AMA), upper arm fat area (AFA) and the sum of skinfold thickness (SumSF) were calculated by using

calculation formula of Frisancho (1990).

The ages of the participants were estimated to the nearest 1.0 year and 5 years for children and adults, respectively using the following information: 1) their birth order within the villages, 2) matching their birth to local or national events, and 3) through interviews with people from the neighbor agricultural people who knew their own actual age and could compare their ages to the ages of the children. The age from X+0.00 to X+0.99 years old were defined as X years old, and analyzed as X+0.50 years old (Hagino et al., 2013).

Nutritional status of the Baka people

The nutritional status of children was assessed using two methods. The first method required the data to be converted to z-scores using two child growth reference datasets. The height-for-age z-score (HAZ), weight-for-age z-score (WAZ), weight-for-height z-score (WHZ), and BMI-for-age z-score (BMIAZ) were calculated using the Center for Disease Control 2000 reference (CDC2000: Kuczmarski et al., 2002). The upper arm circumference-for-age z-score (UACAZ), triceps skinfold thickness-for-age z-score (TSFAZ), subscapular skinfold thickness-for-age z-score (SSFAZ), arm muscle area-for-age z-score (AMAAZ), arm muscle area-for-height z-score (AMAHZ), arm fat area-for-age z-score (AFAAZ), and sum of skinfold thickness-for-age z-score (SumSFAZ) were calculated from the United States reference (NHANES I and II: Frisancho, 1990). A z-score below –2 was defined as malnutrition (WHO, 1986), and based on this definition the prevalence of

malnutrition was calculated.

Secondly, BMI classification method using sex-age specific BMI cut-off references (IOTF cut-off; Cole et al., 2000; Cole et al., 2007) were applied. Based on these IOTF cut-offs, each participant was classified as either Thin, Normal, Overweight, or Obesity. The Mann–Whitney U-Test was used to assess the sex differences among the BMI classifications.

The nutritional status of adults was assessed by calculating BMI and percent body fat. Two equations of Durnin & Womersley (1974) and Siri (1956) were used to estimate the participants' percentage of body fat. Adults' BMI were classified into four categories using three cut-offs, 18.5, 25, and 30 (WHO, 2000).

Curve smoothing

The LMS method (Cole & Green, 1992) was used to develop the sex-specific smoothed growth curves for height, weight and BMI. The LMS method is a mathematical smoothing method that involves a process to normalize the original data using a Box-Cox transformation. This method contains three distribution curves representing the median (M), coefficient variance (S), and skewness (L) as a Box-Cox power. The fitting process was performed by changing these three values (L, M, and S) to smooth the data across each age and standardized the original dataset as a normal distribution. The same smoothing method was applied when developing the international growth references (e.g., the CDC2000 reference: Kuczmarski et al., 2002 and the WHO2006 reference: WHO, 2009). The LMS Chart Maker Pro ver.2.2

(Medical Research Council, UK) program was used to develop the LMS model. The goodness of fit of the curve was established using the Q-test (Pan & Cole, 2004) and worm-plotting (van Buuren & Fredriks, 2001). The smoothed median curves for height, weight, and BMI were then compared graphically with the CDC reference curves (Kuczmarski et al., 2002).

Statistical analysis

All values are shown as mean ± SD. All statistical analyses were performed with the JMP 11.0.0 software package (SAS institute Inc.). The level of statistical significance was set at $P < 0.05$.

RESULTS

Nutritional status

The mean and standard deviations (SD) for the anthropometric dimensions for the boys and girls at each age are provided in Table 1. Figures 1 and 2 present the smoothed height, weight, and BMI growth curves for the Baka children as well as the CDC2000 curves (Kuczmarski et al., 2002). The height and weight curves for the Baka children were generally below the 3rd percentile of the CDC reference children. The BMI curves had a similar tendency in boys and girls, with the curves above the 50th percentile up to seven years old and then remaining between the 25th and 50th percentiles thereafter.

Table 2 shows the mean and SD of the z-scores derived from the reference data

(Frisancho, 1990; Kuczmarski et al., 2002) as well as the percentage of malnutrition. The number of participants in each BMI-classification group based on IOTF cut-off is provided in Table 3. Because of their small stature and light weight as shown in the growth curves (Figures 1 and 2), the means for HAZ and WAZ were below –3 and –2, respectively, for both sexes. Ninety-five percent of the children were classified into the "stunting" category based on the HAZ result (HAZ < –2) and nearly 70% were "underweight" according to the WAZ result (WAZ < –2). However, through using two indices that standardized by height, the mean values of WHZ and BMIAZ were approximately zero, and the percent of "wasting" (WHZ < –2) were less than 5% for both boys and girls. In addition, greater than 80% of the children (2–20 years old) had a normal BMI. There were significant differences between the sexes for UACAZ, TSFAZ, AMAAZ, AFAAZ and SumSFAZ. There was no significant differences among the BMI classifications (P = 0.88).

Figure 3 shows the distribution of BMI and %fat of Baka adults on the body composition chart, and table 4 contains the characteristics of adult physique and body composition, and the classifications by BMI and %fat. There were significant sexual differences among all anthropometric indices except for BMI. Males were significantly taller, heavier than females. Males had larger upper arm circumference and arm muscle area; however, two sites of skinfold thickness (triceps and subscapular) and % body fat were greater in females. About 80% of adult participants had normal ranged BMI (18.5 ≤, < 25), and less than 15% of adults were classified into thin. The distribution among BMI

classification was similar between children and adults (Table 3 and 4).

DISCUSSION

Nutritional status of Baka hunter-gatherers

The nutritional status of the Baka children was considered to be in a moderate level. The height and weight curves were below the fifth percentiles of the CDC reference. In addition, the HAZ and WAZ were low in boys and girls. In general, the low HAZ suggested chronic undernutrition while the low WAZ suggested acute undernutrition. Because of the small physique of the Baka adults, Baka children are shorter and lighter than reference children of the same age. Therefore, it is considered difficult to predict nutritional status based only on indices that depend on age. In contrast, the indices that standardized weight by height suggested a different tendency. BMIAZ were moderate and only 5% of the children were classified into the "thinness" category. In addition, over 80% of children had normal BMIs based on the IOTF cut-offs (Cole et al., 2000, Cole et al., 2007) and the WHZ means (both 0.11 in boys and girls) were above the reference median (WHZ = 0). Three percent of the children were classified as "wasting". This rate of "wasting" was lower than other sub-Saharan African populations (de Onis & Blössner, 2003), and the BMI smoothed growth curves ranged between the 25–75 percentiles of the reference.

The body composition z-scores indicated that the Baka children had a lean physique compared with the US reference population (Frisancho, 1990). Four z-scores relating to the

upper arm, UACAZ, TSFAZ, AMAAZ, and AFAAZ, were approximate or below -1 compared with the US reference. This suggested that the Baka children had less muscle and body fat than US children of the same age. In contrast, the SSFAZ (–0.09 in boys and –0.13 in girls) suggested a moderate amount of body fat on the trunk. Moreover, when standardizing the amount of upper arm muscle by height, the AMAHZs (0.26 in boys and 0.42 in girls) were greater than zero for both sexes. Based on this result it was considered that Baka children have a greater amount of muscle compared with US reference children. Similarly to HAZ and WAZ, each z-score that is compared with the reference by age might be underestimated because of the small final body size of the Baka adults. However, irrespective of this limitation, our results suggest that the body composition of Baka children was similar to and in specific examples leaner than that of US reference children.

The adults' anthropometric characteristics also indicated the moderately good nutritional status among adults' participants. The mean values of BMI were normal ranged in both sexes, and those of %body fat were considered to be proper. Two females had exceeded body weight (66.8 and 69.5 kg) for their moderate height, and one male was extremely smaller (131.3 cm) than other males. The maximum of the height was 167.1 cm (male) and 163.1 cm (female), there were total 57 males and 2 females who were higher than 160 cm. Froment (2014) reviewed the anthropometric studies conducted on Pygmy population in central African rainforest area from mid-1900s to recent 2000s. Only the Gusinde (1955) paper of which field survey were conducted in 1948 gave smaller mean stature of Baka adults

(male: 145 cm and female: 130 cm), other papers provided similar values of Baka adults' height which were ranged 153.1 – 155.6 cm for Baka males, and 146.1 – 149.5 cm for females (Vallois & Marquer, 1976; van Eijk, 1986; Yamauchi, 2000). These all studies were conducted in Republic of Cameroon, thus it should be notable that the adult height of Baka people did not changed in this 30 years. As previously reported by Travaglino et al. (2011), the secular trend among Baka people were not existed, and there also might not be a drastic change of nutritional status or the genetic admixture with non-Pygmies populations.

A shortage of food is one of the primary factors responsible for malnutrition in children. Particularly, insufficient protein intake causes severe malnutrition and faltering growth (Waterlow, 1972; Allen, 1994). In a study of Baka adults, Yamauchi et al. (2009) reported that energy intake and expenditure of Baka adults were well-balanced and sufficient protein was obtained from game, fish, and the ants in both a semi-settlement village and a forest camp. Upper arm anthropometric measurements are also useful indices for assessing nutritional status or energy intake (Frisancho, 1974; Bishop, 1981), and Baka participants largely had proper arm circumference and muscle area. These indices of physique and body composition indicated that Baka children were generally well-nourished, and might be involved the adequate food intake over the mid to long-term.

III-2. SECULAR TREND OF NUTRITIONAL STATUS

METHODS

The field surveys were conducted three times—September 1996, August 2010, and August–September 2011—at the same village located in the southeast of the Republic of Cameroon. The study was conducted in the village over 13 days, 14 days, and 9 days, respectively.

Anthropometric Measurements and Age Estimations

Anthropometric dimensions, including height, weight, upper arm circumference and two sites of skinfold-thickness were measured using standard protocol (Weiner & Lourie, 1981). Height was measured to the nearest 1 mm using a field anthropometer, and weight was measured to the nearest 0.1 kg using a portable digital scale. Upper arm circumference (UAC) was measured with a glass measuring tape. Skinfold-thickness was measured at the triceps and subscapular sites to the nearest 0.2 mm using a skinfold caliper (Holtain, Briberian, UK). Anthropometric measurements were performed for all inhabitants who stayed in the village during each study period. Because most participants did not know their exact ages, their ages were estimated at 1-year and 10-year rates for children and adults using the following methods: 1) Sorting in order of birth, 2) matching their birth dates with local events, and 3) interviewing a local assistant who was well educated, lived in the nearby villages, and knew the participants well.

Nutritional Status and Growth Patterns

The nutritional status of children was assessed by using Z-scores. Two reference datasets were used to convert the children's anthropometric data to Z-scores. The height-for-age Z-score (HAZ), weight-for-age Z-score (WAZ), weight-for-height Z-score (WHZ), and BMI-for-age Z-score (BMIAZ) were calculated using the reference provided by Center for Disease Control (CDC) (CDC2000; Kuczmarski et al., 2002). The upper arm circumference-for-age Z-score (UACAZ), triceps skinfold thickness-for-age Z-score (TSFAZ), subscapular skinfold thickness-for-age Z-score (SSFAZ), arm muscle area-for-age Z-score (AMAAZ), arm muscle area-for-height Z-score (AMAHZ), arm fat area-for-age Z-score (AFAAZ), and sum of skinfold thickness-for-age Z-score (SumSFAZ) were calculated from the United States reference data (NHANES I and II; Frisancho, 1990). A Z-score below -2 was defined as malnutrition (WHO, 1986) and was used to determine the prevalence of malnutrition. The nutritional status of adults was assessed by measuring BMI and percent body fat. Two equations of Durnin & Womersley (1974) and Siri (1956) were used to estimate the participants' percentage of body fat. Adults' BMI were classified into four categories using three cut-offs, 18.5, 25, and 30 (WHO, 2000).

To evaluate the growth pattern, the Preece-Baines model I (PB-1; Preece & Baines, 1978) was adopted for fitting children's height data into the following formula:

$$H = H_1 - [2*(H_1 - H_\theta) / (s_0^{(t-\theta)} + s_1^{(t-\theta)})]$$

H represents height at time t, h1 is a final height, hθ is a height at time θ, s0 and s1 are rate

constants, and θ is a time constant. The Preece-Baines model is a family of curves used to fit the human growth curve. This model is often used to analyze longitudinal datasets on an individual, but it can also apply to cross-sectional datasets (de Onis et al., 2001; Zemel & Johnson, 1994). For performing the curve-fitting, we used the mean age for each age group. The age group was classified into 1-year intervals, in which 2.0–2.9 and 3.0–3.9 years of age, for example, were grouped as 2.5 and 3.5 years old. Some biological parameters were calculated to indicate children's growth patterns (e.g., VTO: height velocity at take-off; APHV: age at peak height velocity).

Census Data Collecting

Demographic datasets were obtained for each *de facto* population and *de jure* population. The *de facto* population is a concept under which individuals were presented and recorded in a certain geographical area during the observation periods. The *de jure* population is a concept under which individuals were recorded as the residents in the geographical area. Because anthropometric measurements were conducted for all people who stayed in the village, the numbers of *de facto* population members for each generation were obtained from anthropometric studies. The numbers of the *de jure* populations for 2010 and 2011 were obtained from a census study. During the census study, the interviewer visited each residence, interviewed the number of residents, and obtained individual data including name, sex, and marriage status. The numbers of *de jure* populations in 1996 were substituted by the numbers

of the *de facto* population.

Statistical Analysis

Because of the limited number of participants, the datasets obtained in 2010 and 2011 were united as the 2010–2011 population. As the 1996 population had previously been analyzed in our study (Hagino et al., 2011), the datasets for the 1996 generations were used in these same datasets. The mean value of the Z-scores (1996 vs. 2010 and 2011) were examined by the t-tests. The biological parameters calculated from the PB-1 function were compared between 1996 and 2010–2011, and then these were compared with our previous cross-sectional study with large samples (Hagino et al., 2013). Adults' body characteristics for 2010–2011 were compared with those listed in our previous study (Yamauchi et al., 2000), which used the same datasets as that for 1996.

All statistical analyses were performed with the JMP 11.0.0 software package (SAS Institute Inc). All values were shown by Mean ± SD. The level of significance was set at $P < 0.05$.

RESULTS

Table 1 shows the mean values and the standard deviations of Z-scores for boys with percentages of malnutrition ($Z < -2$). Significant generational differences were found in three indices, the TSFAZ, AMAAZ, and AMAHZ ($P < 0.05$). The 1996 generation had a

significantly greater amount of upper arm muscle for their age or height than did the 2010–2011 generation. The percentage of "stunting (HAZ < –2)" for each generations was more than 95%, and that of the "underweight (WAZ < –2)" was about 80%. On the other hand, less than 20% of the participants were classified into "wasting (WHZ < –2)," and the percentage of "thinness (BMIAZ < –2)" were less. As for boys, mean values, standard deviations and percentages of malnutrition for girls are shown in Table 2. There was no significant generational difference found among 11 Z-scores. Although there were fewer participants who were classified as stunting or underweight than as boys, the percentages in each of those categories were extremely high in both generations. However, there were only a few girls who were defined as wasting or thinness.

Table 3 contains some biological parameters for child growth, which were calculated from the PB-1 mathematical parameters. Each parameter was compared between generations 1996 and 2010–2011, and the population of the largely sampled cross-sectional study. Ages at take-off (ATO, in years old) were similar among the three populations, both for boys (11.31, 10.70, and 10.67) and for girls (9.23, 9.75, and 9.30). Adolescence duration (AD, in years) was almost equivalent between the two generations for both boys (3.88 vs. 3.77 years) and girls (2.94 vs. 3.07 years). For both sexes, there was no great difference in velocity at take-off (VTO, cm/yr); however, peak height velocity (PHV, cm/yr) showed a slightly different trend between the two populations. The PHV for the 1996 boys (6.98) was greater than those of the other two boys' populations (4.56 and 4.88). In addition, the PHV of the 2010–2011 girls

(5.47) was slightly greater than those of the others (4.98 and 4.71).

The anthropometric characteristics of the adult participants are shown in Table 4. Significant generational differences were not found in all the indices. The mean values of BMI for each four generation-sex group were within the normal range (18.5 <, ≤ 25). Similarly, for percent body fat, they had normally ranged mean values (< 20% for males, < 30% for females). Table 5 shows the proportions for the adults' BMI classifications. For each sex-generation group, over 70% of the participants had normally ranged BMI values. There was no significant generational difference between the proportions for both sexes (P = 0.82 for male, and 0.66 for female).

The research duration (days), numbers of the population *de facto*, and the population *de jure* were shown in Table 6. The numbers of population *de jure* were almost similar among the three generations and were estimated to be about 220. On the contrary, the numbers of population *de facto* were greatly decreased. In addition, the percentage of people who stayed in that village during the study periods is also shown in that same table. As the population *de facto* decreased, these percentages greatly decreased.

DISCUSSION

Socioeconomic and environmental variations often influence the physical characteristics of a community's inhabitants (WHO, 1986). It is known that these effects appeared as a secular trend in terms of adult height, children's height, weight, and tempo of growth, among other

measurable factors (Cole, 2003). This study is one of the few studies that followed up with the inhabitants of the same village of Baka Pygmy and examined the relation between the sociological factors and the nutritional statuses of its inhabitants.

Two Z-scores (WHZ and BMIAZ), which were standardized by height, indicated the sufficient weight gain among Baka children. A WHZ score of less than –2 is a sign of acute malnutrition and indicates wasting. WHZ detects child growth for the short term, and often marks decline due to a short-term food shortage or an acute illness. The mean WHZ values of Baka children ranged between –1 and 0. Additionally, the proportions of wasting were much lower than those of stunting or underweight for both sexes (Table 1). The ratio of participants who were classified as wasting (8.4%) was higher than the ratio represented by Cameroonian statistics (5.8%); however, it was lower than the mean value as measured in all African countries (10.4%; United Nations Secretariat, 2011). Moreover, the mean values of BMIAZ for all groups were above –1, and less than 10% of children were classified into thinness category. These results should be considered in relation to the fact that Baka children have proportional body weight for their height, which is equivalent to what is found in the case of the US reference children.

Although the mean values of HAZ and WAZ were extremely low, the tempo of child growth was not considered adversely affected. WAZ is known as a brief indicator that reflects children's nutritional status, and HAZ is strongly related to skeletal growth; thus, low HAZ is often accompanied by long-term malnutrition or growth faltering (WHO, 1986). The mean

values of HAZ and WAZ were very low for both sexes, and for both the generational groups of 1996 and 2010–2011 (Tables 2, 3). Furthermore, almost all the participants were defined as stunting or underweight (90% and 70%, respectively). However, biological parameters did not indicate growth retardation in our participants. ATO is the parameter for timing the start of the adolescent growth spurt, and it is known to be influenced by nutritional status during early childhood (Kulin et al., 1982). Similarly to the findings of our previous study (Hagino et al., 2011), ATOs for Baka children in each generation appear earlier than for the Gambian children (Boys: 12.2; Girls: 10.19, in years old; Billewicz & McGregor, 1982), and they are comparable to the rates found in developed countries. The final body size of Baka adults as measure in the present study (Male: 152.7 cm, 48.3 kg; Female: 146.8 cm, 45.1 kg) was found to be much smaller than the CDC 2000 reference population (Male: 176.7 cm, 70 kg; Female: 163.5 cm, 57 kg; Kuczmarski et al., 2002); thus, the HAZ and WAZ of Baka children were considered to be greatly underestimated.

The secular body size trend was not observed in either children or adults. There was no significant generational difference among the height, weight, arm circumference, BMI, and percentage of body fat for adults for both sexes (Tables 4, 5). Mean BMI values and adult percent body fat were normally ranged, and 70% of adults had BMIs within a normal range. As we previously showed, four Z-scores (HAZ, WAZ, WHZ, and BMIAZ) were almost the same between the generations. In addition, the timing and duration of the adolescent growth spurt did not changed drastically. These indices about growth tempo, childhood nutritional

status, and adult body size suggested that the nutritional statuses of inhabitants in this village were considered generally good, and this had not changed for 15 years.

Similar to the effect found for body size, the secular trend for the body composition of children was not found to exist. Upper arm circumference and skinfold-thickness strongly reflect energy or protein intakes. As shown in Tables 1 and 2, there was no significant generational difference, except for boys' TSFAZ, AMAAZ, and AMAHZ. Because anthropometric surveys were performed by different researchers (TY for 1996, IH for 2010–2011), an inter-observer bias for triceps skinfold-thickness might be present. However, all of the mean AMAHZ values were above zero, so that should mean that the Baka boys and girls had a greater amount of upper arm muscle than did the US reference children. In addition, only a few children were classified into the malnutrition category ($Z < -2$), and no child whose TSFAZ, SSFAZ, AFAAZ, or SumSKAZ were lower than –2 was included. These results indicated that Baka children had sufficient body muscle and body fat, and that their body composition was unchanged over time.

Three times of census surveys showed that the numbers of *de jure* population was unchanged; however, the numbers in the *de facto* population during research periods got decrease. Although the research period in 2011 was shorter than in the other two surveys, the proportion of the *de facto* population to the *de jure* population in 2010 was clearly lower than that proportion in 1996 (Table 6). The Baka in this village still remained attached to their semi-nomadic lifestyle in 2010–2011. They often stayed in the forest camp for some days, or

even for a few months. Previous studies described various reasons for them staying in the forest: (1) gathering edible wild plants for each season; (2) long-term foraging expeditions (called *molongo*) for acquisition of game or animal protein (Yasuoka, 2006); and (3) avoiding conflicts with other people in their village (Oishi, 2010). Figure 1 shows the locations of the forest camps for the Baka people around the target village in 2010. We obtained five camps' locations by the side of the large river that borders the Republic of Congo; 66 Baka people (30.8% of the *de jure* population) stayed in these forest camps, and all the members returned to the village during the study period. On the other hand, about 18% of village residents did not come back to the village.

Additionally, there was some generational variation for the distribution pattern of the settlement in the village. The distribution pattern for 1996 is shown in Figure 2, and that for 2010 is shown in Figure 3. The plain circle signifies a residential area for the Baka, and the slashed shapes represent the living areas of the surrounding ethnic groups (agriculturists, merchants). The numbers in each circle show the number of Baka residents. For 15 years, agriculturists migrated into the center of the village. Moreover, the residential area for the Baka dispersed and became more marginalized. There were fewer than five households of agriculturists in 1996; however, that number grew greatly in 2010 (30–40 households according to our interview and 45 households, according to Oishi (2012). In addition, a logging company established their base in a nearby village, and then a local hotel and some bars were built in the center of the village. Since many residents assemble in the bar until late

at night, some Baka families moved to other residential areas to avoid the noises and loud sounds in the night. The migrations of other ethnic groups and the influx of companies in neighboring villages produced changes in the population distribution, and this would serve to increase social stress for the Baka people.

The numbers of new births and deaths indicated a slight trend toward a natural increase in this village. The number of births (5) and deaths (3) during 12 months were obtained from interviews with an agriculturist informant and from census data from 2010 and 2011. The crude birth rate was 23.4, and the crude mortality rate was 14.1. These values indicate equivalent mortality and slightly lower fertility compared to statistics of Cameroonian residents (CBR: 35.7, CMR: 13.2; United Nations Secretariat, 2011). Due to the lack of longitudinal census data from 1996 to 2010, it is not possible to discuss population growth rate during these 15 years; however, the tendency for population growth was observed in a short period (2010–2011), with social stress increasing. These trends suggested that the nutritional status of the residents was secured at a generally good level.

The nomadic lifestyle of the Baka people was thought to contribute to maintaining their nutritional status, despite increasing social stress. Yamauchi et al. (2009) targeted Baka adults living in the same village, and they described their energy intake and expenditure as being well-balanced in both the village camp and the forest camp. On the other hand, their TEI and TEE were lower in the village camp than in the forest camp, thus implying that staying in the forest is more healthful for the Baka people, as they can subsist in a more active

manner. Furthermore, it is also revealed that they can acquire adequate energy and protein in the forest throughout the year (Sato et al., 2012; Yasuoka, 2006). As Oishi (2010) described, staying in the forest camp freed them from many of the stresses of the village, and their traditional lifestyle was thought to reduce the stress in their daily lives.

IV. CHILD BEHAVIOR, PHYSICAL ACTIVITY

IV-1. DAILY PHYSICAL ACTIVITIES AND TIME-SPACE USE IN VILLAGE CAMP

METHODS

A field survey was conducted during short dry seasons of 2011, 2012, and 2013 in Baka village located in East Region of Cameroon (Fig. map). Total 127 children (61 boys and 66 girls), and 51 adults (27 males and 24 females) who lived in a village (about 80-100 total inhabitants) participated in this study. The village is 5 km away from the nearest town, and the inhabitants were only Baka people. Children usually went to school in neighboring village; however that school broke up for the summer during the research periods. Children were divided into four age groups (1C: Childhood; 2J: Juvenile; 3A: Adolescent; and 4Y: Youth) by physical development stages using ages of the onset of adolescent growth spurt (Bogin, 1999; Hagino et al., 2013). All children were healthy, and were not contracted any disease.

Age estimation

All ages of the participants were estimated by three following methods; 1) birth-ordering of children within a village, 2) interviewing their birth date for local informants, and 3) matching their birth date with national/local events. As a result, we could obtain their estimated age to the nearest 1- and 10- years for each children and adults, respectively.

Daily time allocation

Each participant (total 178 persons) wore the small GPS (Global Positioning System, WPL-2000, Wintec) units for consecutive 3 days including the sleeping time (Fig 1). GPS units which have recently been downsized and lightened, can provide useful information about time and location for recording human daily activities (Furusawa, 2012). GPS log points which including latitude and longitude at each time point were obtained for total 518 person-days. Unfortunately, data of 16 person-days (3.0%) were lacked or excluded by some reasons as flat batteries, wearing failures, and one case of driving with a car. Figure 2 shows the sample of daily track obtained from GPS log data. Solid line means a travel route, and dotted line means an active radius.

The daily travel durations (hours/day) were calculated for activity areas. Using the GPS log data and direct observations, activity areas surrounding their village were divided into following 6 areas (their own village, forest, river, water, village of other ethnics, and miscellaneous) shown in figure 3. “Forest” surrounded their village, “River” was located about 900 m away from the village, and some "Other villages" located near the target village (figure 3). “Own village” was defined as a circle which includes all houses and that radius was about 50 meters, and “Water” was about 150 m away from the center of the village (figure 4). “Miscellaneous” included the nearest town, their small cultivated land, and a trunk road faced to the village. Travel durations (hours/day) were determined as a period between the time of leaving from their village and that of returning their village. If the participants

visited two or more sites in a trip, the travel durations were divided for each area by checking the tracking points. The trend of daily time-space using for children were evaluated from comparing travel durations of 8 sex-/age- groups. Sex-/age- difference of time-space using was assessed by two-way ANOVA.

Daily physical activity

Physical activity monitoring was performed with total 69 children (33 boys and 36 girls) and 42 adults (22 males and 20 females) who were sufficiently physically developed. Each participant wore the pedometer which contains a built-in uniaxial accelerometer (Lifecorder EX, Suzuken, Japan) with GPS units at the same period. Younger children were excluded because of their small physiques which were not to be able to wear accelerometer units. Finally, 325 (205 of children and 120 of adults) person-days of acceleration data and step counts were obtained.

The physical activities of children were assessed by four indices. From the GPS log data, daily travel distance (TD, km/day) and active radius (AR, m/day) were calculated for each person-day. TD was determined as the sum of distances participant moved for a day, and AR was calculated as the radius of the smallest circle which included all the GPS log points for each day (shown as figure 2). Daily step count (steps/day) was obtained from pedometer, and physical activity level (PAL) for each day was calculated for both total 325 person-days. PAL is determined as the ratio of total energy expenditure (TEE) to basal metabolic rate

(BMR), and widely used for assessing the physical activity. PAL was directly calculated by converting activities levels (0, 0.5, 1–9) which were recorded in every two minutes in accelerometer to METs using regression equation previously developed by Ainsworth et al. (2000) and Kumahara et al. (2004). PALs were calculated as the values which multiply average of converted METs and 1.1 as the ratio of resting metabolic rate (RMR) and BMR (Institute of Medicine, 2005) together. Sexual differences were evaluated by non-paired t-test. Steps and PAL of children were compared with international references (Tudor-Locke et al., 2004; FAO, 2004). Furthermore, the duration of sleeping time (minutes/day) of 315 person-days were also estimated from acceleration data.

Correlation between daytime use and physical activities

The Pearson's correlation coefficients were calculated between 4 indices of physical activities (TD, AR, steps, and PAL) and travel durations for each activity area (Own village, Forest, River, Water, Other village, and Miscellaneous). The time staying at their village were divided into two categories which were village (awake) and village (sleep), thus total 28 variations of coefficients were calculated.

Statistical analysis

All statistical analyses were performed by using JMP 11.0.0 software package (SAS institute. inc). All data were shown by mean ± SD. The significance levels were defined as $P < 0.05$.

RESULTS

Table 1 presents the time-space using of participants for divided 8 sex-/age- groups and those of adults were also shown as a reference. The cells show the mean daily travel durations (min/day) to six activity areas for each group. In general, there were three findings for time-space using of children. At first, the older groups (3A and 4Y) generally went out from their own village more than younger groups (1C and 2J). Secondary, the daily time allocation was almost same in younger boys and girls, whereas varied in older groups. At last, children generally spent their time mainly in villages (of their own and other ethnics) and forest. From the two-way ANOVA, the sex-/age- differences were observed for five activity areas except the area "Water".

Table 2 presents the means and standard deviations for four indices about physical activities of children, and table 3 shows the classifications of steps and PAL by means of international recommendations (Tudor-Locke et al., 2004) and reference (FAO, 2004). There was no significant difference among steps, PAL, and AR. The mean values of steps, PAL, and TD were generally greater than those of adults. The means of daily steps among children were exceeded 20,000 counts, and 94.1% of obtained daily steps were greater than the counts of developed country's children and international recommendations (Tudor-Locke et al., 2004; Owen et al., 2009). The means of PAL were also high in both sexes, where Table 2 shows that 52.6% boys' person-days and 63.4% girls' person-days were classified as "vigorous" based on the criteria established by FAO (FAO, 2004). Figure 5–8 shows the increment of total travel

distance (TD) and active radius (AR) of children. As their age increased, TDs were become significantly longer and AR were become significantly greater (r = 0.52 – 0.66, $P < 0.0001$). The variations of TD and AR among individuals were observed in older boys. Table 4 contains the correlation's coefficients among 4 indices about the physical activities. There was strong positive correlation between steps and PALs (r = 0.90 and 0.75, $P < 0.001$). There were also strong positive correlation between steps and TDs (r = 0.85 and 0.81, $P < 0.001$) and ARs (r = 0.50 and 0.40, $P < 0.001$). The coefficients were generally higher in boys than girls.

Table 5 presents the correlation between physical activities and time-space using. There was moderate relationship between daily time-space using and physical activity. Travel durations for “Forest” and “other village” had generally significant positive correlations between physical activity indices, whereas the travel durations for “Own village” generally had negative correlations. Travel durations for “Miscellaneous” had significant positive correlation between only TD and AR. Trip for "River" significantly increased only TD, and travel duration for “Water” didn’t have any significant relationship between physical activity indices.

DISCUSSION

From direct observations in the settlement village camp, it was found that the six divided areas have different characteristics for children’s activities. In “Own village”, children often spent time with their family, and their common activities were sleeping, resting, some

housework and personal activities, and playing. Except some cases like game of tag and dancing, their playing activities in village such as chatting, singing, drumming, painting, and babysitting were mostly being sedentary. On the contrary, children become physically active in “Forest”. Children walked bush road continuously, and participated various activities such as fruit gathering, bail fishing, line fishing, and small animal hunting. Sometimes they played with hanging tree vine, cutting narrow trees by machete, and made some craft by leaves or twigs. “River” located little a bit far from village (about 900 m), children mainly spend their time for playing in river or personal activities as laundering and bathing. “Water” was near from the village (about 150 m), children visited for fetching water as housework usually, or sometimes for laundering. There are some “Other villages” of agriculturist population around Baka village. Older children and adults visited there to have communication at daytime or drinking alcohol at night, or sometimes for wage works in nearby cultivated land.

The variations in time-space using between older boys and girls were considered to be generated by the major livelihood of adults. The most important livelihood of adult Baka women is gathering daily provisions in the forest. One of reasons young girls went to forest for longer than boys was that they took along with their mothers’ food procuring in forest. Travel durations for “Forest” were continuously increased in girls, and that time was greater in youth girls (243 minutes) than that of female adult in present study (203 minutes) and the time Baka women spent for gathering in forest camp (137 minutes: Yamauchi et al., 2009). On the contrary, times of older Baka boys stayed in “Forest” (176 minutes by adolescents and

152 minutes by youths) were less than that of male adults (210 minutes). Hunting and gathering activities generally need much physical strength, and previous studies showed that Baka people conducted hunting activities wider range than gathering yam tubers (Yasuoka, 2006; Sato et al., 2012). Recent hunting activities by Baka people are conducted by snare hunting, and this approach does not cost many time after setting snares. However, it needs much amount of purchased wires, and Baka boys seldom own sufficient amount of these products. They have to walk around in the forest barehanded or with small machete and sometimes participated small animal hunting by group contained 2–4 boys. Because this approach cost much physical intensity, not all boys joined the foraging. Some older boys went into the forest together, and others stayed at the village and participated other sedentary activities. Older boys also spent considerable time to visit “Other villages”. Baka adult and youth men often participated in public relations to other ethnics. The time durations visited “Forest” and “Other villages” both significantly increase TDs and ARs (Table 5). As shown in figure 7 and 8, the variation of AR in older boys (400 – 1400 m) were greater than that of older girls (450 – 1,100 m). The gender role about daily food procurement and social function also might generate variations of TDs and ARs in older children.

There was a strong positive correlation between heights and TDs ($N = 120$, $r = 0.59$, $P < 0.0001$). Pontzer & Wrangham (2006) showed that developments of body lengths make daily travel distance increase, and it is possible for adults to travel longer than juveniles with same energy cost in their study for Chimpanzees. For both boys and girls, it got be easier to

go farther and change their trend for space using with their physical development. As the total travel distance increased, the travel distance on dirt bush road in the forest also increased. The physical development of Baka children were considered to be reached nearly adult level at 14 – 18 years old (Hagino et al., 2013; Scammon, 1930). The physical activity levels among children were maximized at adolescent in general (Tudor-Locke et al., 2004). However, it is also notable that younger children walked 3 – 8 km per day, and spent about 60 – 120 minutes to stay in the forest. The youngest participant was 2 years old, and all participants could walk by their own foots. Not only older children went out from the village, younger children also tried and tended to stay outside of the village camp.

The Baka children had high levels of physical activities which might explained as a result of lots of walk caused by long time of foraging or trip to other villages. Previous studies generally reported that the physical activities are vigorous during childhood or adolescence, and then decline with becoming adulthood (Ndiaye & Bénéfice, 2007; Sherar et al., 2007; Tudor-Locke et al., 2011). The mean ages of acceleration-monitored children in this study were 13.7 (ranged in 6–18) and 12.0 (ranged in 8–16) years old for boys and girls, respectively. Almost of these children (91.3%: 63 of 69) were determined as adolescents or youth. The intensity of daily physical activity was especially high in adolescent group. The mean step counts of 3A boys were 30,469 (n = 15, SD = 6,016), and the maximum value was 43,468 as the average of consecutive 3 days. 3A girls also had greater step counts (24,899 ± 4,440, n = 21). The mean values of PAL were above 2.0 in both 3A boys (2.19 ± 0.18) and 3A

girls (2.09 ± 0.12). These values were higher than those of 4Y boys (mean step counts = 20,376 and mean PAL = 1.91) and 4Y girls (mean step counts = 22,376 and mean PAL = 1.91).

Similarly to Yamauchi et al. (2009) revealed, there was strong correlation between steps and PAL. Daily steps are known as the indices which reflect physical activities (Welk et al., 2000), and that trend would appear clearly in traditional lifestyle society. Ntandou et al. (2008) and Sobngwi et al. (2002) described that the inhabitants of traditional or rural societies had high physical activities in some sub-Saharan countries. From the questionnaire survey for adult population, they revealed rural inhabitants walk more frequently and had longer time of moderate / sedentary activities than urban inhabitants because of the difference of major subsistence and environmental factors. Our participants were mainly engaged in traditional hunting or gathering subsistence (also they had a small cultivated land nearby the village), and they were isolated from neither public nor private transportation because of the geographical and economic reasons. Needless to say when they go into the forest, Baka people always had to travel by their foot even they visit the spot faced to a road as they were short of money to catch the private transportation like motorbike taxies. Yamauchi et al. (2009) reported that the physical activities of Baka people greatly reduced in semi-settled village. In that study, the mean values of PAL in the village camp were reported as 1.41 for males and 1.56 for females which categorized as “very low” or “low” levels (FAO/WHO/UNU, 1985; Yamauchi et al., 2009). Because of the difference of participants' ages (children vs. adults) and calculating

methods (acceleration monitoring vs. factorial methods), it is not appropriate to compare the mean values of PAL directly; however, the PAL of our adult participants were considered to be proper, and older children participants certainly had high level of physical intensities.

It was considered that going out from village generally have positive correlation with higher physical activity level, and housework and personal time do not significantly increase the physical intensity. Because of limited village radius (about 50 m), if they played long time in their village, it is considered difficult to increase their physical activities greatly. By contrast, children always walk around in forest or trunk road, their step counts and physical activity level increased. Harold & Karen (1998) described that there were some (e.g. physiologic, environmental, psychological and social) factors which influence physical activity development of children. According to physical development and skills acquisition about viability in the forest, children tend to go out from village and visit some areas. The physical and psychological developments in older children made them possible to choose various daily activities based on “the expansion of accessible area” and “initiation of participation to adult’s livelihood”. The time-space use of Baka children were changed as their age increased, and that change was drastically occurred at the timing of the initiation of adolescent growth spurt. As children physically developed and their time using changed, the daily travel distances (TDs) and activity radii (ARs) significantly increased, and also related the increment of children’s physical activities.

IV-2. CHILD BEHAVIOR AND FOOD PROCUREMENT IN FOREST CAMP

METHODS

The author accompanied the Baka on a short-term hunting camp planned by the inhabitants of the Baka village, and observed the children's activities and their contribution to food acquisition. The foraging trip was conducted for 8 days in the end of September 2012. The foraging camp was conducted twice. The first trip was 8 days in the end of September in 2012 comprised of 22 people: 3 married men, 3 married women, 10 unmarried children over 10 years old (6 boys and 4 girls), 4 children from 2-9 years of age (2 boys and 2 girls), and 2 female infants below the age of two. The second trip was 12 days in the end of August in 2013 comprised of 44 people: 6 married men, 6 married women, 12 unmarried children over 10 years old (5 boys and 7 girls), 19 children from 2 – 9 years of age (8 boys and 11 girls), and one female infant below the age of two. Total numbers of participants for these foraging camps were 410 (172 boys and 238 girls) person-days of children and 156 (78 males and 78 females) person-days of adults. The children's ages were estimated by birth reordering of children and comparing their birthdates to local events (Hagino et al., 2013).

During the foraging trip, direct observations of a total of 16 children (eight children for each sex) were conducted. The ages of the 8 boys were ranged 5 – 18 years. The eight girls were ranged 6 – 17 years old. In the Baka community, children are often classified into three age groups which are: *dindo* (infancy), *yande* (childhood-juvenility), and *wanjo* / *sia* (adolescent boys and girls, respectively) (Brisson & Bousier, 1979). In this study, children

were grouped into three age classes, which are infants (*dindo*, below the age of two), younger children (younger *yande*), and older children (older *yande* and *wanjo* / *sia*) by the recognition from the inhabitants. The 16 observed children were divided into 4 groups (younger boys, younger girls, older boys, and older girls). The numbers of participants from each group was 4 persons, respectively. During the daytime (starting at 06:00 and ending at 18:00), the author observed participants carefully. Their activities were noted whenever they changed and recorded to the minute (Yamauchi et al., 2000).

All foods brought back to the camp were identified and weighed using a digital kitchen scale (Tanita KD-160, Japan) and a digital scale (TanitaTF-205, Japan). Animals were identified with the aid of Kingdon's book (1997). The value of energy and protein they contained was calculated using the African food composition table (Leung, 1968) and the Standard Table of Food Composition in Japan (Ministry of Education, Culture, Science and Technology, Japan, 2005). According to Hayashi (2008) and Hattori (2012), Baka adults hunt animals in many ways (e.g. with their hands, machetes, spears, guns, and snares), and Yasuoka (2014) and Sato et al. (2012) describe that snare hunting becomes more important during long-term camping. In this study, because of the limited period of this camp, snare hunting and gun hunting were not carried out. In addition, cassavas and plantain bananas were carried into this foraging trip because of the following reasons: 1) this camp was not located so far from settlement village, 2) the number of children was greatly larger than that of adults, and 3) most of participating children had not experienced a traditional foraging trip.

RESULTS

Table 1 shows the time usage of 16 Baka children for certain categories. 141 variations of activities were observed, and were classified into following 11 categories: (Hunting/Fishing, Gathering, Travelling (Forest), Travelling (River), Household, Personal, Sleeping, Resting, Playing, Strolling, and Accompanying). The time Resting is defined as physically inactive activities which included taking a rest with lying, sitting, and standing position. Some communicating and chat are also included in this category. Accompanying was defined as cases of children did not participate into the activities even though they view some activities of hunting, gathering, fishing, and household. The sex-age difference among time allocation was assessed by two-way ANOVA. The time of Travelling (Forest), Playing, and Strolling were significantly influenced by age effect. Times for social activities (Household and Personal) and times for repose (Sleeping and Resting) were unchanged. Time of Travelling (River) was influenced by sex effect, and Gathering was influenced by significant interaction effect.

Table 2 contains the mean of time allocated to various types of hunting, gathering and fishing activities. The time children spent hunting was mostly spent rat (giant pouched rat) hunting, and older boys spent a longer amount of time doing so. Except for rat, children faced to the hunting scene of tree hyrax. Three fishing activities, line fishing, bail fishing, and poison fishing were observed. Bail fishing was mainly conducted by girls, and line fishing was done by younger boys. During the observation period, poison fishing was carried out

twice. The author observed only once with an older girl (Day 14), and another case (Day 11) was missed because the observed child of the day did not participate that poison fishing. In addition to edible food gathering, cash crop gathering activities were also conducted. Honey gathering by children was not conducted.

Table 3 contains the total weight of foods brought back to camp during the observation period. There were 24 species including some with vernacular names. From 7 species of animal game (three species of mammals and four species of reptiles), the total more than 45,000 grams of fresh meat was obtained. These values were included: 26 rats (Figure 1: 18,075 grams in fresh and 1,130 grams after prepared), 3 hyraxes (Figure 2: 7,322 grams), one small galago (Figure 3: 236 grams), 2 vipers (Figure 4: 6,800 grams), one serpent (96 grams), and 10 tortoises (Figure 5: 13,071 grams). 10 vernacularly named freshwater fish and two crustaceans (Figure 6: crabs and shrimp) were caught during fishing. Though the shells of crabs were disposed of, all of its other parts like tissue, bones, and entrails of aquatic fauna were eaten in a soup. Wild yams (Figure 7) were gathered by adult males, then brought back and distributed in camp. On the contrary, honey (Figure 8) was eaten nearby a tree by the people who discovered or worked to gather honey while only a small amount of honey was brought back to the camp.

DISCUSSION

Baka children frequently participated to food procurement activities. Almost of all children were took part in food acquisition every day, and they spent longer time than Baka adults did. From the early childhood, Baka children went out from their camp over a half of the daytime, and accompanied older children or adults to their hunting and fishing activities. As their age increased, Baka boys decreased time for line fishing and greatly increased time for game hunting whereas Baka girls were not changed their pattern of food procurement activities (Table 2). Children faced many chances of small animal hunting; however, the success rate of their small animal hunting activities was not high, and their quarry was consequently relatively small. During this period of short-term foraging, children and adults acquired food differently. While adults tended to go into the forest and act alone, children tended to act in groups of 4 – 8 persons. In addition, the kinds of food brought back were differed between adults (e.g. tortoises, or vipers) and children (e.g. rats, or galago). Adults generally brought back bigger and heavier species of animal food resources, and the total amount of food adults acquired was also large.

The time usage of Baka children

Baka children in forest camp were considered to be generally physically active, and they participated in food procurement activities the same as the Baka adults. Children generally spent total of 2 – 3 hours on these activities, and these times were relatively longer than adults

did (men: 151 minutes; women: 137 minutes) as described by Yamauchi et al. (2009). All 16 children participated in some kind of food acquisition activities every day, and 13 children went outside of camp for more than half of daytime (6 hours). Time for travelling outside camp increased (from 30 – 60 minutes to meanly 120 minutes) after their initiation of adolescent growth spurt. Moreover, the time of Accompanying decreased which meant children become act autonomously as they grew. In the sedentary village, older Baka children stayed in the forest for over 2 hours per day, walked more than 10 km on average, and their step counts exceeded 20,000 steps (Hagino & Yamauchi, 2014). Same as in the village, the Baka children stayed in forest for considerable, and their physical activities were considered to be vigorous.

Playing time was significantly decreased as children's age increased. The following are the play activities observed among adolescent children and their total times: "Figure 9: swinging and hanging on vines (634 minutes)", "wood and bush cutting with a machete (333 minutes)", "chatting (261 minutes)", "romping around with older children (Figure 10: 227 minutes)", "dandling a baby (Figure 11: 213 minutes)", "small trap making (80 minutes)", "chasing with other children (74 minutes)", "singing a song (67 minutes)", "climbing up trees (32 minutes)", "bows and arrows playing (Figure 12: 29 minutes)", "small stone or branch throwing (25 minutes)", and "bird mimic (2 minutes)". In hunter-gatherer society, child playing is strongly associated with learning the complex knowledge and skill, is necessary to be a productive and competent member of their traditional societies (Bock, 2002). Harako

(1980), Hayashi (2011), and Kamei (2005) described that many of hunting and gathering activities by the Pygmies' children have the aspects of play or gaining experience rather than immediate food acquisition. In some activities which relatively little technique or physical strength are required, such as in bail fishing, gathering activities, or playing with vines, younger children accompanying older children was observed outside of the camp. Younger children played with other younger children in the camp mainly, especially in their houses. On the other hand, older children moved together only with those in their same age group for long-term forest travel, and hunting/foraging activities. Compared to some sedentary activities in the camp, most activities in the forest require adequate physical and mental development from children. During early childhood when physical development is inadequate, children spent their time in a safe area. Then as they grow, they start to expand the range of their activity area and go out from the camp.

During the transition from childhood to adolescence, the time for subsistence work increases (from 15% to 20 – 40% of daytime) whereas time allocated for playing decreases by about half (from 70% to 31 – 40% of daytime) in Yora and Mikea societies (Sugiyama & Chacon, 2005; Tucker & Young, 2005). Older Hadza children spent a longer time than younger children (4 – 6 hours vs. 2 – 4 hours per day) away from their camp (Marlowe, 2005), and could obtain a certain amount of returns in some conditions from the foraging trips (Hawkes, O'Connell, & Jones, 1995). Crittenden et al. (2013) described Hadza children in Tanzania sometimes brought back up to 50% of their individual energy requirements from the

fruit, nuts, and tubers they gathered. The returns by children generally increase as they grow, as shown in the study of Bird & Bliege-Bird (2005) where Martu adolescent children earned nearly three times as much as juvenile children earned per hour foraging. Additionally, it is also known that a dramatic increase in daily food acquisition occurs, especially in male initiates 10 – 15 years old (Gurven & Kaplan, 2006; Kaplan et al., 2000). Boyette (2012) reported that Aka children spent about 25% of their time on working activities. Although Boyette (2013) also found that Aka children (4–16 years old) spent more than 50% of their daytime on leisure activities, they spent a considerable amount time on subsistence work, just as other hunter-gatherers children did.

The details of food procurement activities by children and their returns.

Children often participated to small game hunting which cost high labor against the low success rate and low returns. Children usually perform rat hunting in a group that contains at least 3 – 4 people. Rat hunting starts when children find a burrow hole in the ground during their travels in the forest. Because rats build their nests underground and they dig tunnels that lead to the surface of the earth, children seek out and stop up as many holes as possible near the first hole they find at the beginning of the hunt. Children thrust their hands or tree branches into the burrows to check their direction and junction (Figure 13). Simultaneously, they search for the existence of barricades, feed and feces in the tunnel. If there are no clues, they dig up the ground along the rat tunnels with their machetes and extend the search area.

Older children deduce whether or not there is a rat in the burrow from the dryness or smell of the items they find. Sometimes they argue about the sex of the rats (as they said, male rats make barricades near the surface, and female rats make them deeper). When they judge that a burrow is occupied, the children who have discovered the burrow call over neighboring children, and they hunt systematically. They cut up surrounding plants, then stuff dry leaves in the first hole and set fire to it with live coals (Figure 14). Then, they smoke out the rats, and wait until the rats run out from the burrow or suffocate inside. Only 1 or 2 children work nearby a hole, while the other children wait around the burrow holding wooden sticks. When the rat runs out, all of the children pursue it and try to hit it with a wooden stick or their bare hands. If there is no response or change after 15 – 30 minutes of smoking out the burrow, the children dig it up and search for rats until they appear or the children give up. These operations often require a long amount of time. There were 15 cases in which children pursued rats, and they cost a mean of 38 minutes (with a minimum of 6 minutes and a maximum of 146 minutes) from the moment they found a burrow until the hunting process was finished (in either caught or failed). During the 16-day of observation period, there were more than 50 cases where children found burrow holes; however, only 5 rats were caught by children. Although a large amount of time and number of children were spent on rat hunting, the success rate was not comparative to the expenditure. In addition, the weight of each rat was not so large (about 500 – 900 grams); thus, children may procure game inefficiently by rat hunting alone.

The bail fishing cost considerable time per process; it was relatively fruitful for children. Contrary to line fishing (Figure 15), which was done by one person, bail fishing (Figure 16) was usually performed in groups containing about 4 – 8 children. Adults often go with at least 1 or 2 people when they bail fish, while children always go with groups of more than 3 people. During bail fishing, branches and dirt are heaped up on a section of the shallow stream, which is 1-2 meters wide. A bank height is normally 20 – 30 cm high, and it holds the flow of the river back temporarily (Figure 17). During these process, older children usually cut down the tree branches and dig up the soil (Figure 18). Younger children carry those branches and clods of earth to the stream, and bank them up as a soil wall. Then they divide all participants into small units containing 2 or 3 people, and move along the stream. While younger children have a basket to put fish in, older children always use a machete or a leaf to extract water (Figure 19). They stop in front of the small hollows of the riverbed or clods that have been pushed out in the river, and look for some aquatic fauna like small fish, crabs or shrimp by removing water, overturning stones, or searching under the riverbank. They repeat these processes until the soil wall upstream collapses and the water flow returns to normal (Figure 20). At the end of bail fishing, the children gather again, then scrape the mud off of the fish, and remove their scales (Figure 21). Over the course of 16 days, bail fishing was directly observed 6 times total. Bail fishing took 128 minutes on average (with a minimum of 47 minutes, and a maximum of 255 minutes) from the start of making the soil wall until they headed home.

Rat hunting and bail fishing need a comparable amount of time and number of children. Children spent a longer time on rat hunting (1,263 minutes) than bail fishing (676 minutes) during the total observation time (11,520 minutes) during this foraging. The sum of crude weight of obtained foods by children was greater from bail fishing (13,735 grams) than those from rat hunting (5,765 grams in fresh and 256 grams after prepared). Children also brought back 2,900 grams of a tree hyrax, 236 grams of a galago, and 118 grams of small tortoise; however, total amount of returns from child hunting activities were relatively smaller than those from fishing activities. Moreover, the calculated energy and protein content from bail fishing were also greater than from hunting (14,648 kcal vs. 7,847 kcal, and 2,004 grams vs. 1,325 grams).

Despite greater total numbers of person-days, children could obtain smaller amount of forest food than adults, and the food procurement ability among children were roughly estimated at 1/4 – 1/3 of adults. Table 4 compared the energy and protein contents in food brought back to the camp by three groups of children, cooperation, and adults. The numbers of total participants were 156 person-days in adults and 376 person-days in children except infants. Energy and protein daily acquisition in one person-day were estimated 256.1 kcal and 36.1 grams by adults, and 91.6 kcal and 12.9 grams by children. Human protein requirement are proposed 0.66 grams/kg body weight per day in adult population, and 0.69 – 0.75 grams/kg body weight per day in children under the ages of 18 (FAO/WHO/UNU, 2007). The mean values of our participants' weight were 46.1 kg in adults, and 22.9 kg in children.

Surprisingly, without snare hunting, adults could their gain sufficient protein (118.6 %) whereas children did not attain their requirement (78.2 %).

Additionally to hunted game, Baka adults brought back various forest food resources like yam tubers and honey. Two cases were observed that children dag the yam out of the soil. They spent about an hour and gained tubers with minimum damages; however, one yam tuber was very small and there were no edible portion, and another was found to be inedible piece. Also in honey gathering, children could not participate well. Boys tried to climb up the trees frequently; however, they stopped at several meters from the ground because they could not get a suitable foothold or adjusted their wood strings well (Figure 22; as shown in Vallois & Marquer, 1976: p. 166). Even if some males set an example (Figure 23), most of the boys could not imitate them completely. By various tries of food acquirement activity, Baka children could not bring certain amount of foods; however, children view many cases of game hunting and accumulated the experience of hunting to be competent adult foragers.

Accompanying and relationships among children and adults

Some patterns of accompanying between children-children, children-adults were observed, and it is thought that these relationships are associated with children's acquisition of knowledge and skills, or the improvement of their food procurement skills. Although boys tended to act in groups, male adults usually acted alone, and the types of animals brought back were also different between boys and adults.

There were some male adults (estimated to be in their mid-30s) and a grandfather (estimated to be 50+) in the camp, and food procurement was generally performed by young males. The grandfather mostly stayed in the camp and spent his time manufacturing beds and small racks, repairing hand axes and machetes, mending houses, and taking care of infants for short periods of time. Young males foraged every one or two days with hand axes, spears, and small pouches. It was noted from interviews that they almost never accompanied in the daytime foraging, additionally, the author seldom met and accompanied to male adults during the direct observation of 16 children in forest.

Mothers and grandmothers tended differently to male adults. There was one grandmother who had finished bearing children and young mothers who were still reproductively active. These young mothers (estimated to be in their mid-30s) came to the camp with their husbands and children, and some of them had small infants. The mothers with infants spent most of their time taking care of their babies and the children in the camp. They also spent time for cooking food brought back by their husbands, or gathering some firewood nearby the camp. In contrast, young mothers without infants and grandmother (estimated to be 50+) were very active and often participated in food procurement. They usually accompanied older girls, and went to bail fishing almost every day during the camp period.

As children grew, children proceed through several life stages that are defined by physical, behavioral, or emotional development (Bogin, 1997), and become competent adults by gaining skills through experiences and social learning (Bock, 2005). From our

observations and quantitative data we examined the drastic changes in Baka children's behaviors and their patterns of accompanying others as their life stages changed. From infancy to early childhood, children mainly act with older children or adults, especially in their families, and are cared for by them. Their area of activity was mostly inside of the camp, and they rarely went out from the camp unaccompanied. When children grow into juveniles, they begin to accompany other juveniles or adolescent groups. They prefer participating in older children's activities to staying in the camp or the house. Juvenile children tend to join many activities happening around them; however, they usually play a supporting role in them, and seldom make any contribution. As they grow into adolescence, children begin to act autonomously, and their role changes to include executing the main part of food procurement. They view hunting-gathering scenes many times and learn skills and knowledge. As a result, older children generate greater returns even though they spend same length of time hunting and gathering as younger children. In the last stages of their development, with their physical strength and skills fully matured, behaviors vary greatly between boys and girls. Despite Efe, Mbuti, and Aka adolescent children of archers or net hunters become to accompany adults group (Bailey, 1991a; Ichikawa, 1982), Baka boys tend to act alone or in smaller units. Also in their adult stages, they normally conduct foraging alone or only with their families. On the other hand, Baka girls continue to act in groups that contain various age groups. After they engage in reproductive stages and even during post-reproduction, Baka females often act with children and play an important part in facilitating children's acquisition of skills and

experience with food procurement.

Limitation and further study

There was some seasonal and environmental limitation in this study. In a previous study observed foraging trips (Yamauchi et al., 2009), the time allocated to gathering by Baka adults was much greater (132 minutes for males, and 137 minutes for females). Adults mainly participated to wild yams collecting as staple foods need for caloric sufficient. Most of former foraging trips (Sato et al., 2012; Yamauchi et al., 2009), almost all hunting activities were conducted with snares; therefore, they only needed a little time for patrolling or attending to trapped animals. The variation of animals hunted by foraging camp participants was differed to those of previous studies (Bailey, 1991a; Sato, 2012; Yasuoka, 2006). Normally, dykers are the most important animals during foraging camp (Yasuoka, 2014); however, no dykers were caught during this camp period. The study site was nearby provincial town, and the hunting pressure was considered to be relatively high, thus small biont were only caught. Since they did not snare hunt and carried staple foods into camp during the period of our study, the time spent on food gathering was relatively decreased. In addition, the number of children was also greater than adults, that is, the setting of these observations was hardly considered altogether natural. However, in this study, the author would like to emphasize that children tended to participate food acquisition activities avidly, and they could have bring back considerable amount of wild foods in some situation.

Appendix: Brief notes on the daytime allocation of 16 Baka children.

Day 1: 12-year-old boy

He got up early in the morning and went out of the camp to go line fishing. He got back to camp at 06:10, and rested until 06:38 at home. He spent time until 09:30 playing with younger children (1 and 7 years old) and resting in the house repeatedly. At about 10:00, he started travelling in the forest with some older boys, taking a rest occasionally. At 12:00 they went back to the camp and took a rest, and chatted in the house. From 13:01, he went into the forest with the older boys, and carried a machete. They found a rat burrow at 13:20, and caught 1 rat (412 grams) after 20 minutes of hunting, then went back to the camp. At 14:03 he arrived at the camp and went to the forest alone to cut firewood. He went back to the camp at 14:37, and took a rest in the house. From 14:47 he went and did line fishing alone but didn't catch any fish. Then he walked around the forest with 5 older boys again from 16:12. They found the burrow of a rat once but didn't catch it. They went back to the camp at 16:42, and took a rest in the house. Adults carried honey back to the camp and he ate it with the other children. At about 17:00 he went to the river to fetch water and gathered some raffia palm fronds that were growing in the riverside and carried them back to the camp. At 18:00 he was weaving palm fronds to make roofs and taking care of an infant.

Day 2: 14-year-old boy

He got up at 06:25, made a fire and cooked cassavas, then ate them. At 06:55 he accompanied

a group of girls to go bail fishing. On his way he joined up with 3 boys and travelled in the forest apart from the girls' group. He stayed in the forest and participated in hunting rats, climbing trees, and making traps, and then arrived at the camp at 08:21. He left the camp with his machete in a group of children (4 boys and 3 girls), and he cut down trees and vines to open a space to play. 1 boy and 2 girls joined up with him and they enjoyed hanging on a vine for leisure for an hour. At 09:42 he quit playing with the vine and travelled in the forest again with 4 boys and 5 girls (9-18 years old). 2 boys joined up on the way, they hunted rats 6 times and caught 2 rats (804 grams and 947 grams). They went back to the camp at 15:03, approximately 5 hours after he left the camp. From 15:09 to 15:21 and 15:40 to 16:12 he went to cut firewood. Finally, he spent his time sitting and lying down until the end of the day.

Day 3: 15-year-old boy

He got up at 07:18 and kept still in his dome house. Because it was rainy in the morning, he spent most of the time on lying down, and sitting and chatting in front of a fire in the house until past 13:00. At 13:19 he started travelling in the forest with 4 older boys (12-15 years old). In 2 hours of travel, they found one rat burrow but they missed the rat. They went back to the camp at 15:19, cooked bananas and ate them. From 16:01, he started travelling in the forest with the same 4 older boys again. He started bail fishing at the stream at 16:52, and went down the river towards the camp as he participated in bail fishing. At 18:04 he went back to the camp.

Day 4: 15-year-old girl

She got up at 07:02 and cooked bananas and cassavas in her house. At 07:35, she went to the river with some girls. After she dug the ground and looked for earthworms, she did line fishing for an hour but didn't catch anything, then went back to the camp at 08:48. Some boys tried to get her to go to the forest, but she declined. She spent time cooking while she was sitting on a wood bench or the bed in the house, grappling with older girls, and hanging on a vine for leisure. At 10:41, she started to travel in the forest with another girl. Then they found a rat burrow and dug at it a little, but then moved on. They arrived at the river at 11:37 and looked for freshwater crabs, which hide underground on the riverside, with another girl. They joined up with a grandmother and 6 girls who had been working at another place, then started bail fishing. She dug the ground to collect soil to make a dam wall in the river. The younger girls were sometimes sitting and watching them, and sometimes they helped to pile up the soil that had been dug. They moved to the lower reaches of the river at 12:24. On the way, the girl repeatedly made small dams, looked for fish, crabs and shrimp in the stream with the decreased amount of water. After they went back to a point close to the camp at 14:55, they gutted a fish and scraped its scales off. At 15:05 the girl went back to the camp and had a break sitting in front of her house for about an hour. The other older girls made a fire and cooked the fish that she caught. From 16:16 to 16:22, she went to the forest to cut firewood, and from 17:00 to 17:05 and 17:46 to 17:49 she went to the river to fetch water. For the remainder of the day and when not collecting water she stayed in the camp.

Day 5: 10-year-old girl

She got up at 06:07, made a fire and sat around. She went out to fetch water at 06:21, went back to the camp, pared cassavas, and cooked them and had a meal at 06:58. For an hour and a half, she sometimes held an infant in her hands, and sometimes played hanging on a vine. At 08:33, she moved to the forest with 5 girls, 2 younger boys and 2 women. During her time in the forest, she mainly participated in rat hunting for 3 hours until 12:41. Her group found 5 burrows, but 4 of them were thought to be empty. However, there was a rat in one of them and they missed it. From 12:41 they moved to the river and performed bail fishing. The girl started to build a wall to make a dam, but stopped her work because it suddenly started to squall. She took shelter from the rain under a nearby tree. At 13:00, she started bail fishing again, but about 30 minutes later she decided to go back to the camp when it started to rain heavily. She went back to the camp at 14:10, and she didn't catch anything that day. She spent time chatting with children, and took a break in the camp for about 2 hours. From 16:26 to 17:06, she played with a vine and sang a song with children in the forest. She stayed in the camp until 18:00 except for an outing to fetch water from 17:43 to 17:47.

Day 6: 13-year-old girl

She got up early in the morning, made a fire in the house, took care of her younger brothers and sisters and cooked cassavas with her mother. Then she played with a vine with children in the forest from 07:08 to 07:40. At 08:17, her father and mother went into the forest. 1 older

girl, her 2 younger brothers and 1 infant went to the river to start bail fishing at 08:26. At 08:32 they joined up with 4 girls. They did small-scale bail fishing with the children until 09:04 but didn't catch anything. After she went back to the camp once, she took a walk again in the forest with one of her grandmothers and 4 girls at 09:21. They started bail fishing in a stream at 09:43 and fished over a period of 3 hours. The girl mainly dug at the ground with a machete as she moved to the stream's lower reaches. She went back to the camp at 12:43, made a fire and cooked the fish that she caught. She took care of her infant sister, played with a vine, messed around with some other girls and had a break in the house from 13:17 to 15:05. She went to the river to fetch water from 16:30 to 16:33, 16:34 to 16:38 and 16:39 to 16:42, and also went to the river from 17:50 to 17:58 to wash the tortoises that her father caught. At other times, she spent her time in the house or in the camp. She didn't go into the forest again that day.

Day 7: 10-year-old boy

He got up 06:05, and went out camp at 06:18 to go line fishing with three older boys. During the line fishing, older boys mainly had rods, and he sometimes sought worm or stood looking older boys' fishing until he got back to camp 07:51. He stayed in the camp, rested in his dome house, ate small cassava, fetching a water, played hanging a vine and bird mimic with younger children, then he went to line fishing again at 09:58. In this time, he had own rod and participated fishing with two or three younger children until 12:57. During the afternoon, he

mainly played with his sibling by wood cutting, small tree climbing, small trap making, and chasing each other in the camp. He went out the camp at 15:37 for the third time of line fishing. Because of hard rain, he went back to his house at 17:28, and then rested until the end of the day.

Day 8: 5-year-old boy

He got up at 06:35, stayed in his leaf house until 06:49 and sometimes played with his small sister (3-year-old). In camp, he chatted with his sibling, strolled, rested sitting on a bench, and watched other boys played making small traps, wood cutting, and hanging vine. He went into the forest at 10:02, and watched older children played hanging vine. Only a few times he played by vine. He came back to camp at 11:12, and stayed for an hour. At 12:17, he accompanied with older boys went to line fishing. He did not have a rod, mainly carried worm and watched older boys did line fishing. They got back to the camp at 15:04. Until 18:00, he stayed in camp, rested in his house, watched his mother's cooking, sat on a bench, played hanging small vine, cut narrow blanch with machete, or strolled in camp.

Day 9: 8-year-old boy

He got up at 06:20, and went out the camp for line fishing with some older girls until 08:38. During he stayed in camp, he rested, played his small sister (3-year-old), cooked cassava, played hanging small vine. He went fishing again at 09:16 with a younger child and got back to camp 10:42. He chatted with younger children sitting on the bench, sometimes dandled his

sister, hanged vine, made small traps, and rested in his house until 13:04. Then he accompanied older boys' line fishing. He watched their fishing, and sometimes dug a ground searching worm or small fish, or travelling a river with younger children, and gathered caterpillars. They got back to camp at 15:24, and he stayed in a camp until the end of the day by resting in his house, strolling in a camp, hanging vine, assisted cooking for dinner, chatting with other children.

Day 10: 6-year-old girl

She got up at 06:14, sat in her dome house and watched older girls cooking. She ate cassava, and strolled in a camp, hanged a vine, or sat on the wood bench. She went out a camp at 08:24, travelled in a forest and river with two older girls and a younger girl. They started bail fishing at 08:55; however, she did nothing and watched older girls made a dam in the river. During this bail fishing, she sometimes extracted water, and searched fish, but spent most of her time for only watched or carried caught fish in small cage. They got back to camp at 11:50, and older girl started cooking fish, then girls ate them. Until the end of the day, she went out to the camp only three times for bathing in river, play hanging vine, and fetching water. She played with children (mainly younger children and few older girls), chatted with girls, assisted cassava cooking, made a fire, and watched older boy and adult male broke down tree hyraxes by machete.

Day 11: 7-year-old girl

She got up at 06:05, sat and saw an older girl cooked cassava until 06:58. She strolled in a camp or rested in her dome house, and from 07:21 to 07:38, she saw older children and adults disinfest ants (Dorylinae). She went into a forest at 08:09 with two older girls, two younger girls and a younger boy. Travelling in a forest until13:39, they tried small game hunting (rat and hyrax) for 14 times, and caught a rat (1,134 grams). She did not participate in these hunting mainly, she watched older girls digging a ground and fanning a fire, or waited rat came out of the burrow with holding small wood stick. From 13:38, they moved to river, and started bail fishing. She carried small basket, and sometimes dug a ground, bail out water, and caught a fish. Finally, they got back to camp at 17:11. She rested in front of her dome house until end of the day.

Day 12: 9-year-old girl

She got up at 06:37, and sat around a fire in her house. Until 09:12, she stayed in a camp, played hanging a vine, watched other children playing, romped around with girls, counted small cash crops, and chatted with younger children. She went line fishing from 09:12 to 10:09; however, she could catch no fish. She stayed in a camp again for nearly three hours, mainly played with other children. She went into river at 12:54, but got back 13:34 with no food gained. Except for one time for fetching water, she was always in a camp. She assisted cooking by scraping fish off a scale, washing game meat, made a fire, watched other girl

cooking, chatted with other children, rested in her house, and watching other children playing by hanging a vine or palm fiber crafting.

Day 13: 17-year-old boy

He got up at 06:12, made a fire and cooked cassava. He rested and played in his dome house with his sibling until 08:03. Some boys and girls started quarrel, and he watched from his house. Until 10:27, he was in camp and spent his time for cooking small rat, assisted other boy's cooking, chased with his sibling. From 10:27, he and three older boys and an older girl travelled in a forest, and mainly tried rat hunting. They inquired 13 times of rat burrow, and spent total nearly 4 hours for rat hunting. They missed three rats and caught a one rat (1,249 grams). They got back to camp at 15:11, made a fire and started cooking a rat. Until 18:00, He rested in his house or on a bench, chatted with younger children, cooked some food brought back, and little time of play which were hanging a vine and wood cutting.

Day 14: 14-year-old girl

She got up at 06:15, cooked banana in a fire, cleaned and chatted in her dome house. After she finished eating, she went into a forest with three older boys and an older girl at 07:44. Until 09:38, they conducted rat hunting for twice, but she did not participate in positively, and watched other children's actions. From 09:38, she and other older children moved to join to adult group, and started poison fishing. She saw male adults cut down the tree, and then tore

off the bark which contents a poison with other older children. In total, over 15 persons were participated in this poison fishing. After collecting enough amount of bark, they moved to riverside, mashed the bark, and put them in river. She also took part in these activities. Then all participants moved river and caught fish which appeared surface of water and paralyzed by poison. They finished their fishing at 14:59, and washed the fish, remove scales and entrails until 15:35. Finally, they caught total 5,561 grams of aquatic fauna. She got back to camp at 16:07, made a fire, fetched water, and cooked these fish. From 17:03 to 18:00, she spent her time for resting in camp, chatting with girls, and playing hanging a vine.

Day 15: 10-year-old boy

He got up at 06:07, sat around a fire and cooked cassava. He came out from his house at 07:16 and stayed in camp until 08:44. He played hanging vine, chasing with other younger children, or chatted on the bench. From 08:44, he and four girls (two older and two younger girls) went into a forest. They travelled in a forest for an hour and half, joined other children's groups; however, they seldom participate in hunting/gathering activities, gained nothing, and came back to camp at 11:01. He was in camp until 12:08, and went river for playing with younger children by throwing small pebbles and hanging vine for about 30 minutes. He spent almost of his time nearby the camp until the end of the day. He strolled in a camp, made small traps, played with small bow and arrows, pebble throwing for trees, chatting and resting in his house, fetched water once, and playing in river. He usually acted with younger boys (3 – 9 years old).

Day 16: 6-year-old girl

She got up at 06:58 and stayed in her house with her sibling until 07:42. She was in camp until 09:18 by sitting on a wood bench, playing hanging a vine and wood cutting, chatting, and singing songs with other children. During 09:18 to 09:35, she and some girls went into a forest, and gathered termites on wood. Because the rain in the last night, it was so cold all the day. She did not physically active, thus she spent almost of her time in camp. She went to forest again from 13:18 to 14:43; however, she only gathered termites or snails, and did not any other hunting/fishing activities. In the camp, she was also physically sedentary. She rested total 332 minutes in a day, which were the longest time among observed 16 children. She was usually together with her small sister (4-year-old), and spent her time for resting in house, sleeping in daytime for total 58 minutes, singing songs with girls, chatting with her sibling, and romped with younger girls.

SUMMURY OF THE RESULTS

The ecology of Baka hunter-gatherer's children

In this thesis, the author examined the demographic characteristics as basic information and ecological system among Baka hunter-gatherers' children living in rainforest area of southeast Cameroon from the aspects of nutritional status, physical activities, and daily behaviors.

Demographic characteristics obtained from longitudinal census surveys and retrospective family tree interviews showed the comparable level of fertility among Baka population. During the three years of research period, the number of population in target area tended to naturally increased. The crude birth rate was as three times as the crude death rate, and were similar to national statistics of whole land of Republic of Cameroon. The mean value of completed parity of ancient Baka females who appeared in reconstructed family tree was moderate among the modern hunter-gatherer societies. Daughter-mother ratio as an indicator of population increasing rate also indicated the high potential of natural population growth. The relatively low child mortality and high probability of survival until the marriage among recent Baka population was suggested. [Chapter II]

Growth charts including height, weight, and BMI among children, converted z-scores and adult anthropometric characteristics were obtained from a cross-sectional anthropometric survey. As their genetically based short adults' stature, the height and weight of Baka children were generally shorter and lighter than 3rd percentiles of U.S. international reference populations from the early childhood to being fully mature. Z-scores of height and weight for

their ages (HAZ and WAZ) were also lower, where over 90% of Baka children were suspected in chronic malnutrition. However, two z-scores (WHZ and AMAHZ) which standardized the body weight and arm muscle area by their height indicated that Baka children's body weight and arm muscle amount were comparable to those of U.S. children in same height. In addition, over 80% of Baka adults had normal ranged BMI and proper amount of body fat. From these results, the nutritional status of current Baka hunter-gatherer was considered to be well-nourished. [Chapter III-1]

Longitudinal study over 15 years which targeted the same village inhabitants was also conducted in remote area of East Province. Some demographic characteristics like influx and admixture residing among various ethnics indicated the increasing of social stress for the Baka people in this village. However, indices concerning the child physical development, adult body size, and body composition all implied that the nutritional status of the Baka residents was considered to be generally in good level. Additionally, any negative secular trend in their nutritional status was not occurred during the 15-year period between the two survey administrations, even with an increase in social stress. Our results also suggested that the nomadic forest lifestyle among Baka people supported an ability to avoid stress or conflict within their village, and helped to maintain their nutritional status. [Chapter III-2]

Baka children showed a high level of physical activities, and trend of time-space using were drastically changed as their age increased. Younger children stayed almost of their time in own village; however, they stayed meanly a hour in a forest. Older children tended to

go out from their own village and go into the forest or visited neighboring villages. Daily step counts greatly exceeded the recommended values of developed countries, and their daily physical activity level (PAL) was moderate to vigorous level, in general. Travel distance (TD) and activity radius (AR) which calculated from tracked GPS log got significantly greater with the ages of children increased for both boys and girls. TD, AR, and PAL were strongly associated with step counts, thus it was considered that energy expenditure of hunter-gatherer children was fundamentally generated by locomotion. In addition, "going out from the village" makes children's physical activity level significantly greater. [Chapter IV-1]

From direct observations of daily time allocation in the foraging forest camp, it was revealed that Baka children tended to spend considerable length of daily time to food procurement activities even in the childhood period. Total time of hunting, fishing, and gathering extended about 2 – 3 hours per day, which were considered to be comparable or might be greater than Baka adults usually spent. As their age increased, time allocated for "playing" got decreased, and children become concern food procurement activities autonomously and avidly. Without snare hunting, various animal games were gained and large quantity of fish was caught by means of bail fishing, line fishing, or poison fishing. Although the numbers of population and total consumption-days were greater in children, total amounts of obtained forest products were so much greater in adults. For children, probabilities of success in small game hunting were not high, and the energy and protein acquisition by children was more efficient in fishing than hunting. [Chapter IV-2]

CONCLUSION

In the nutritional ecology among Baka hunter-gatherers' children, the relationship among nutritional status, growth and physical development, physical activity and daily behavior, and nutritional intake and food procurement was considered to be circulated immediately, steadily, and stimulatingly (Figure 1).

Baka children had sufficient body weight and muscle amount for their height, and their growth tempo was comparable to developed country children. Also, almost of Baka adults had normal ranged BMI and proper amount body fat, hence the nutritional status assessed from the anthropometric indices among Baka population were considered to be in a good level. In addition, 15-years longitudinal survey found that the nutritional status was maintained in over generations in spite of the social stress increasing.

From accelerator/pedometer monitoring, extremely high level of daily physical activities among Baka children were revealed. The mean step counts were approximately 25,000 – 30,000 per day, and mean values of PAL also exceeded 2.0. As age increased, children tend to go out from their village or camp, and expand their activity areas steadily. Older children (10-18 years old) often visited to other villages and stayed in a forest 2-3 hours for everyday. Step counts were strongly associated to daily travel distance, activity radius, and PAL; hence, it was considered that physical activities of Baka children were fundamentally consisted by walking.

Baka children avidly participate to food procurement activities and tried to acquire

their required energy and nutrients. From the ages of 3 – 6 years old, children stayed in forest for meanly an hour per day, and juveniles (6 – 9 years old) also spend nearly 3 hours for food gathering activities on a daily basis. Although various activities as hunting, fishing, and gathering were performed with large numbers of consumption-days by children, a probability of small animal hunting was relatively low. In a result, the fruit of food acquisition by children was not considerable, and it is considered that children had to depend on adults of their caloric and nutrient intake. However, Baka children avoided wholly rely on adults to gain daily foods, and tried to meet their energy requirement.

The author would conclude these results as following circulations. Firstly, better condition of nutritional status can lead the high level of physical activities and active daily behaviors. Secondly, active daily behavior among Baka children are expressed as participation to food procurement activities. With partially depend on adults of food acquisition, Baka children can fulfill nutrient intake, and sufficient caloric/nutrient intake and physical activities can produce better health condition. While children avidly tried to acquire their provisions, they also acquire knowledge and gain experiences which raise the efficiency and probability of further food procurement. In these way, Baka hunter-gatherers' children become adults and to be independent.

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SOURCE MATERIALS BY CHAPTER

(Numbers refer the chapters in this thesis.)

II : Hagino, I. & Yamauchi, T. (2014). "Fertility and population dynamics of Baka hunter-gatherers in southeast Cameroon". Paper presented at 2nd International Conference Replacement of Neanderthals by Modern Humans: Testing Evolutionary Models of Learning.

III-1 : Hagino, I., Hayashi, K., Kawamura, K., Sato, H., & Yamauchi, T. (2013). Adolescent growth spurt and growth pattern factors related to the short stature of Pygmy hunter-gatherers of southeast Cameroon. Annals of Human Biology. 40(1): 9-14.

III-2 : Hagino, I., Sato, H. & Yamauchi, T. (2014). The demographic characteristics and nutritional status for a hunter-gatherer society with social transition in southeast Cameroon. African Study Monograph, Supplemental Issue, 47: 45–57.

IV-1 : Hagino, I. & Yamauchi, T. (2014). Daily physical activity and time-space allocation of pygmy hunter-gatherers' children in southeast Cameroon. In T. Akazawa, N. Ogihara, H. C. Tanabe, & H. Terashima (eds.) Dynamics of Learning in Neanderthals and Modern Humans Volume 2: Cognitive and Physical Perspectives, pp. 91–98. Tokyo: Springer Japan.

IV-2 : Hagino, I. & Yamauchi, T. High motivation and low gain -food procurement in rainforest foraging among Baka hunter-gatherer's children-. RNMH Project A02 Volume, Tokyo: Springer Japan. (in press.)

FIGURES AND TABLES

Introduction

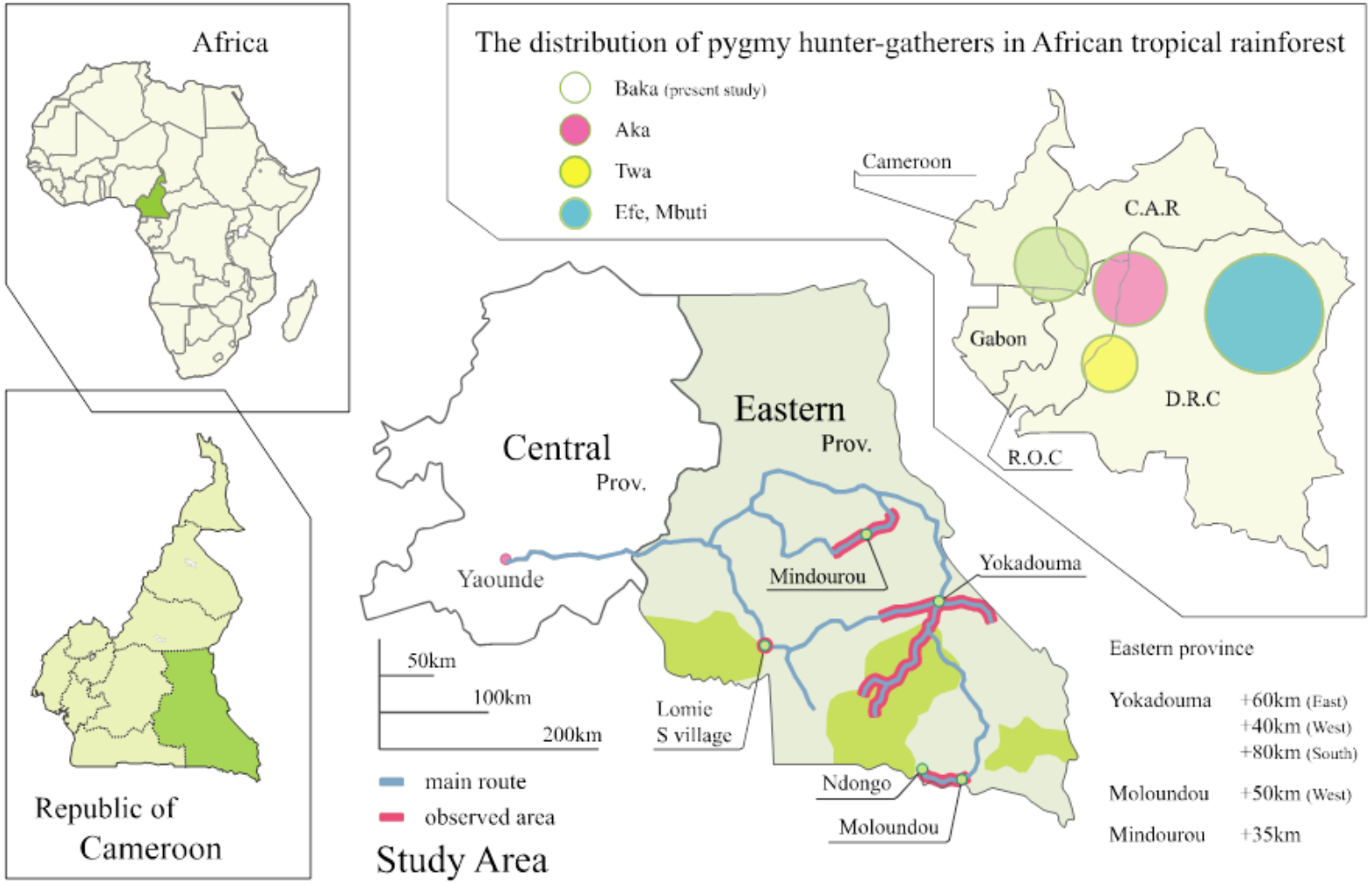

Figure 1 : Maps of study site.

Figure 2 : A village along a trunk road.

Figure 3 : A traditional hut house known as a "*mongulu*" in the foraging camp.

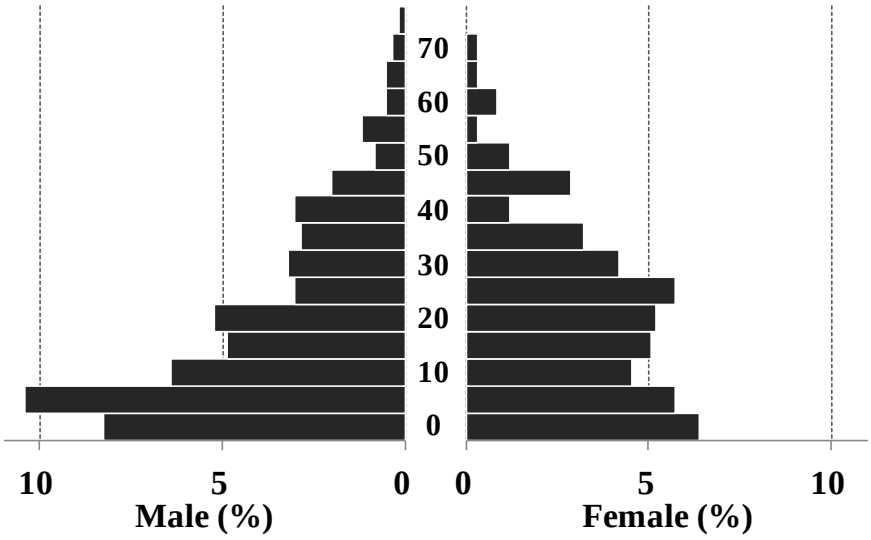

Figure 1: Population structure of target areas in 2011.

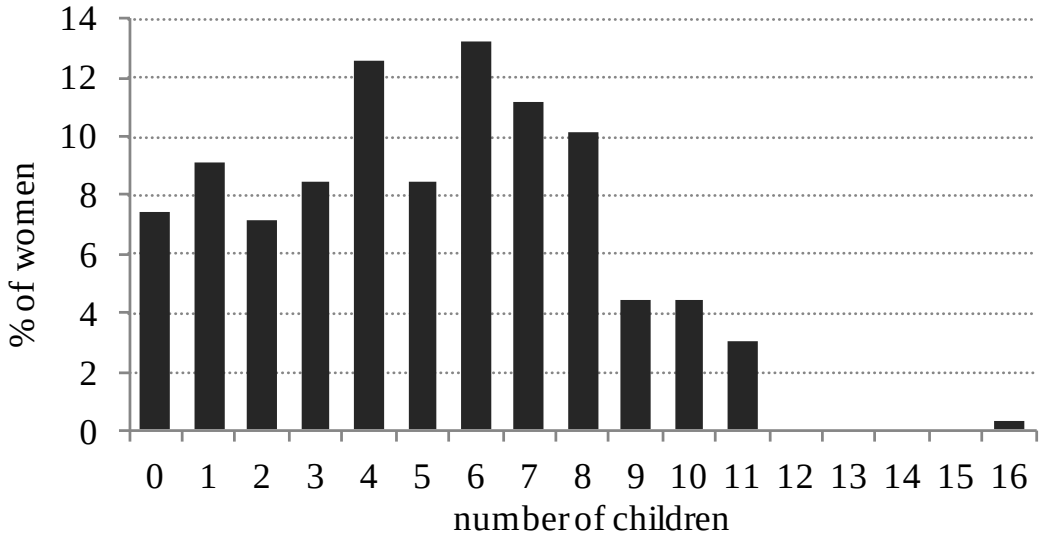

Figure 2: Percent distribution of number of children of both sexes.

Table 1: Population dynamics among 2012-2014.

The numbers of	2012	2013	2014
Total populations	594	589	581
Births (CBR)		24 (40.4)	26 (44.1)
Deaths (CDR)		8 (13.5)	9 (15.3)
Natural increases		+16	+17
Social increases		-21	-25

Table 2: Daughter-Mother ratio (DMR) and estimated Lotka rate (*P*) by mother's age groups.

		No. of married children			*P* at mean child bearing age	
group	N	Male	Female	DMR	20	25
B	88	106	235	2.670	0.050	0.040
C	37	62	83	2.243	0.041	0.033
D	26	38	81	3.115	0.058	0.047
B-D	151	206	399	2.642	0.050	0.040

Tables 3: The fertility among hunter-gatherer societies.

group	Fertility	Study area	Reference
Baka	5.03	Cameroon, rainforest	present study
Aka	5.04	Central African Republic, rainforest	Cavalli-Sforza, 1986
Aka	6.2	Central African Republic, rainforest	Hewlett, 1991
Efe	2.6	DR Congo, rainforest	Hewlett, 1996
Mbuti	5.5	DR Congo, rainforest	Hewlett, 1996
!Kung	4.69	Namibia, Kalahari desert	Howell, 1979
Agta	6.53	Philippine, rainforest	Goodman et al., 1985
Ache	8.03	Paraguay, rainforest	Hill and Hurtado, 1996
Hunter-gatherers	5.6	mean value of 12 groups	Bentley et al., 1993
Horticulturists	5.4	mean value of 14 groups	
Agriculturists	6.6	mean value of 31 groups	

Chapter III-1

Table 1. Height, weight and BMI growth norms, expressed as LMS for Baka boys.

age	Ht				Wt				BMI			
	N	L	M	S	N	L	M	S	N	L	M	S
1.5	11	0.601	71.4	0.055	26	1.411	8.2	0.152	11	0.453	17.1	0.088
2.0	29	0.577	75.9	0.053	33	1.238	9.3	0.147	29	0.478	16.8	0.088
3.0	33	0.569	83.4	0.049	33	0.975	11.2	0.137	33	0.529	16.3	0.086
4.0	38	0.618	89.3	0.047	38	0.861	13.0	0.129	38	0.579	16.1	0.085
5.0	34	0.688	94.8	0.044	34	0.833	14.3	0.124	34	0.628	15.9	0.084
6.0	31	0.750	99.9	0.042	31	0.832	15.6	0.120	31	0.670	15.7	0.082
7.0	28	0.795	104.5	0.040	28	0.839	17.0	0.118	28	0.695	15.6	0.081
8.0	32	0.828	109.0	0.039	32	0.856	18.6	0.115	32	0.694	15.6	0.079
9.0	25	0.848	113.3	0.037	25	0.874	20.5	0.113	25	0.670	15.8	0.077
10.0	28	0.858	116.9	0.035	28	0.870	22.0	0.111	28	0.633	16.0	0.076
11.0	28	0.866	120.1	0.033	28	0.842	23.3	0.109	28	0.596	16.2	0.075
12.0	33	0.885	123.6	0.031	33	0.767	25.0	0.107	33	0.569	16.4	0.073
13.0	31	0.944	128.5	0.030	31	0.533	27.8	0.105	31	0.557	16.8	0.073
14.0	18	1.087	134.2	0.028	18	0.149	31.3	0.102	18	0.564	17.4	0.073
15.0	16	1.318	139.4	0.027	16	-0.133	35.0	0.098	16	0.600	18.2	0.074
16.0	16	1.582	143.6	0.027	16	-0.186	39.1	0.094	16	0.671	19.0	0.076
17.0	23	1.834	146.7	0.028	23	-0.062	42.5	0.092	23	0.783	19.7	0.077
18.0	17	2.059	149.1	0.029	17	0.206	44.7	0.092	17	0.940	20.1	0.079
19.0	16	2.267	151.1	0.030	16	0.572	46.7	0.095	16	1.142	20.5	0.081
20.0	24	2.287	151.3	0.031	24	0.944	48.4	0.098	24	1.376	20.7	0.082

Table 2. Height, weight and BMI growth norms, expressed as LMS for Baka girls.

age	Ht				Wt				BMI			
	N	L	M	S	N	L	M	S	N	L	M	S
1.5	8	-1.728	69.5	0.055	21	0.020	7.4	0.129	8	0.767	16.5	0.087
2.0	25	-2.142	74.0	0.052	29	-0.178	8.8	0.128	25	0.519	16.4	0.085
3.0	27	-2.865	83.1	0.048	28	-0.544	11.0	0.125	27	0.025	16.1	0.082
4.0	28	-3.296	89.6	0.047	28	-0.785	12.6	0.124	28	-0.420	15.9	0.078
5.0	31	-3.415	94.2	0.047	31	-0.890	14.0	0.123	31	-0.704	15.7	0.075
6.0	29	-3.311	98.7	0.047	29	-0.907	15.3	0.123	29	-0.774	15.6	0.072
7.0	25	-3.045	104.0	0.046	25	-0.883	16.8	0.123	25	-0.693	15.5	0.070
8.0	18	-2.684	108.8	0.045	18	-0.850	18.3	0.122	18	-0.554	15.5	0.070
9.0	23	-2.290	112.5	0.043	23	-0.822	19.6	0.122	23	-0.417	15.6	0.072
10.0	21	-1.856	117.0	0.041	21	-0.759	21.6	0.121	21	-0.297	15.8	0.076
11.0	22	-1.413	122.2	0.040	22	-0.558	24.0	0.121	22	-0.164	16.1	0.080
12.0	16	-1.029	126.9	0.038	16	-0.148	26.1	0.122	16	0.002	16.6	0.085
13.0	19	-0.716	131.8	0.036	19	0.374	29.8	0.124	19	0.173	17.3	0.090
14.0	16	-0.471	136.1	0.034	16	0.733	34.3	0.123	16	0.316	18.0	0.095
15.0	20	-0.283	139.6	0.033	20	0.768	37.0	0.121	20	0.409	18.7	0.098
16.0	15	-0.133	142.5	0.031	15	0.550	39.3	0.121	15	0.416	19.4	0.102
17.0	19	-0.022	144.4	0.031	19	0.211	41.7	0.122	19	0.289	20.0	0.104
18.0	12	0.051	145.4	0.030	12	-0.117	43.7	0.124	12	0.022	20.5	0.107
19.0	9	0.094	145.9	0.030	9	-0.339	44.9	0.125	9	-0.365	20.9	0.108
20.0	42	0.119	146.1	0.030	42	-0.467	45.5	0.125	42	-0.809	21.2	0.109

Table 3. Mean and standard deviations of Z-scores, percentage of malnutrition.

	Boys				Girls				*P*
	N	Mean	SD	%Z<-2	n	Mean	SD	%Z<-2	
HAZ	487	-3.45	0.81	96.3	387	-3.49	1.03	94.3	0.55
WAZ	506	-2.67	1.10	71.2	405	-2.55	1.21	64.9	0.14
WHZ	292	-0.03	1.07	4.8	233	0.08	0.84	1.3	0.22
BMIAZ	487	-0.24	1.10	12.9	387	-0.21	0.97	3.4	0.71
UACAZ	483	-0.82	0.61	7.3	399	-1.26	0.63	9.8	< .0001*
TSFAZ	482	-0.53	0.55	0.0	398	-0.79	0.61	0.0	< .0001*
SSFAZ	482	0.04	0.76	0.0	398	0.03	0.70	0.0	0.88
AMAAZ	481	-1.45	0.63	18.7	398	-0.88	0.84	7.0	< .0001*
AMAHZ	304	0.04	1.17	2.3	232	0.23	1.15	0.9	0.06
AFAAZ	481	-0.72	0.41	0.0	398	-0.85	0.46	0.0	< .0001*
SumSFAZ	481	-0.29	0.60	0.0	398	-0.41	0.62	0.0	< .01*

non paired t-test

Table 4: BMI classification of Baka children (2-20 years old)

	Boys		Girls	
	n	%	n	%
Thin	63	13.0	51	12.8
Normal	411	84.2	326	81.7
Overweight	13	2.7	21	5.3
Obesity	1	0.0	1	0.0
Total	488	100.0	399	100.0

references from Cole et al. (2000; 2007)

Table 5: Anthropometric characteristics and BMI/%fat classification of Baka adults

	Male			Female			*P* [9]
	n = 359			n = 401			
Age group							
20-30	131			172			
30-40	123			115			
40-50	66			90			
50+	39			24			
Height (cm)	153.5	±	6.1	146.6	±	5.1	< 0.0001
Weight (kg)	49.4	±	6.9	44.9	±	6.3	< 0.0001
BMI [1] (kg/m^2)	20.9	±	2.0	20.9	±	2.5	ns
UAC [2] (cm)	25.1	±	2.4	24.3	±	2.3	< 0.0001
Triceps (mm)	6.9	±	1.8	11.7	±	4.0	< 0.0001
Subscapular (mm)	9.7	±	2.2	13.5	±	4.2	< 0.0001
AMA [3] (cm^2)	42.5	±	8.1	34.1	±	5.7	< 0.0001
% body fat (%)	14.4	±	3.1	25.0	±	4.8	< 0.0001
Thin [4]	44	(12.3%)		67	(13.7%)		
Normal [5]	307	(85.8%)		314	(78.3%)		
Overweight [6]	7	(1.9%)		18	(4.5%)		ns [10]
Obesity [7]	0	(0.0%)		2	(0.5%)		
Total	359	(100%)		401	(100%)		
Normal weight obesity [8]	11	(3.2%)		42	(10.5%)		

Data are shown by mean ± SD

ns: no significant difference ($P \geq 0.05$)

1: Body Mass Index

2: Upper arm circumference

3: Arm muscle area

4: BMI < 18.5

5: 18.5 ≤ BMI < 25

6: 25 ≤ BMI < 30

7: 30 ≤ BMI

8: 25 ≤ BMI < 30, %fat: 20 < (males); 20 < (females)

9: non paired t-test.

10: Mann-whitney's U-test. $P = 0.56$

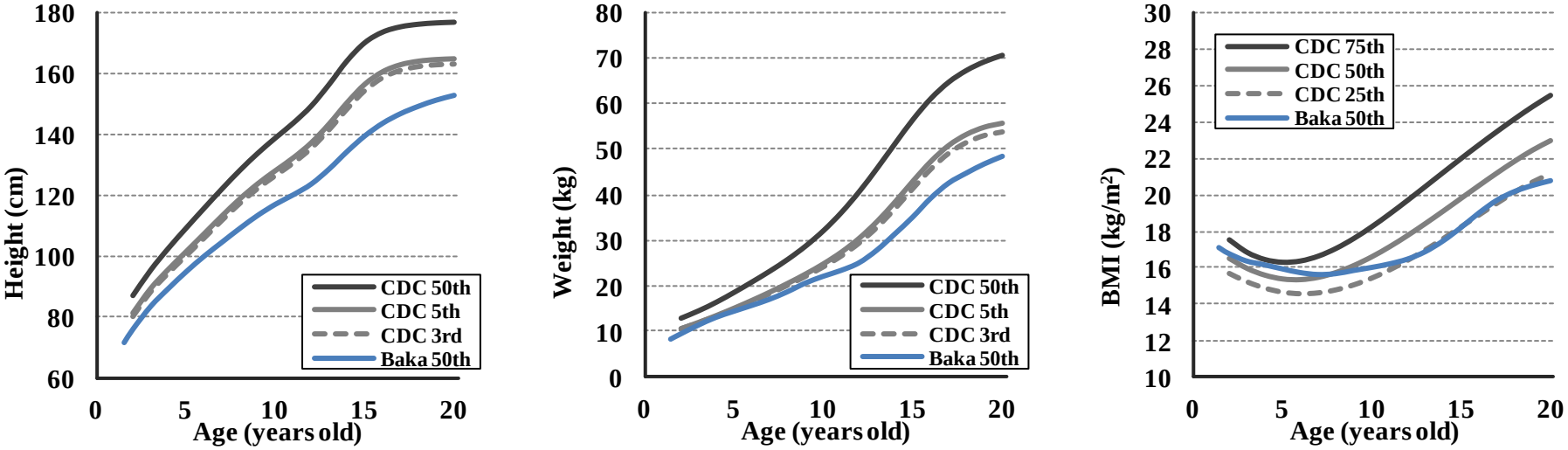

Figure 1: Smoothed height, weight, and BMI curves of median values for Baka boys compared to CDC2000 reference

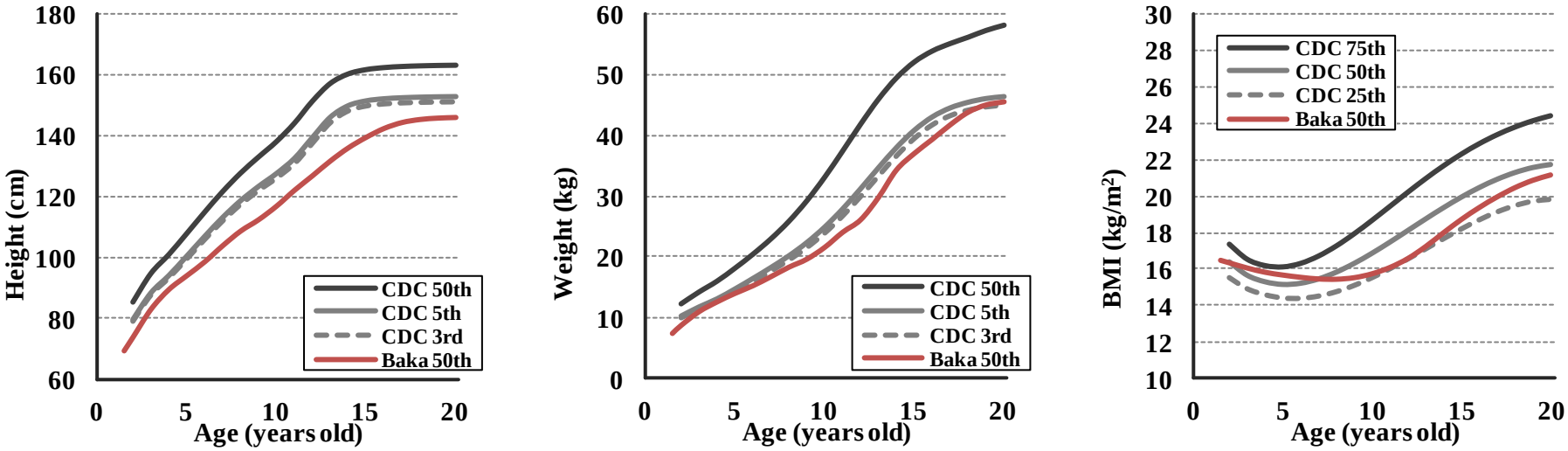

Figure 2: Smoothed height, weight, and BMI curves of median values for Baka girls compared to CDC2000 reference

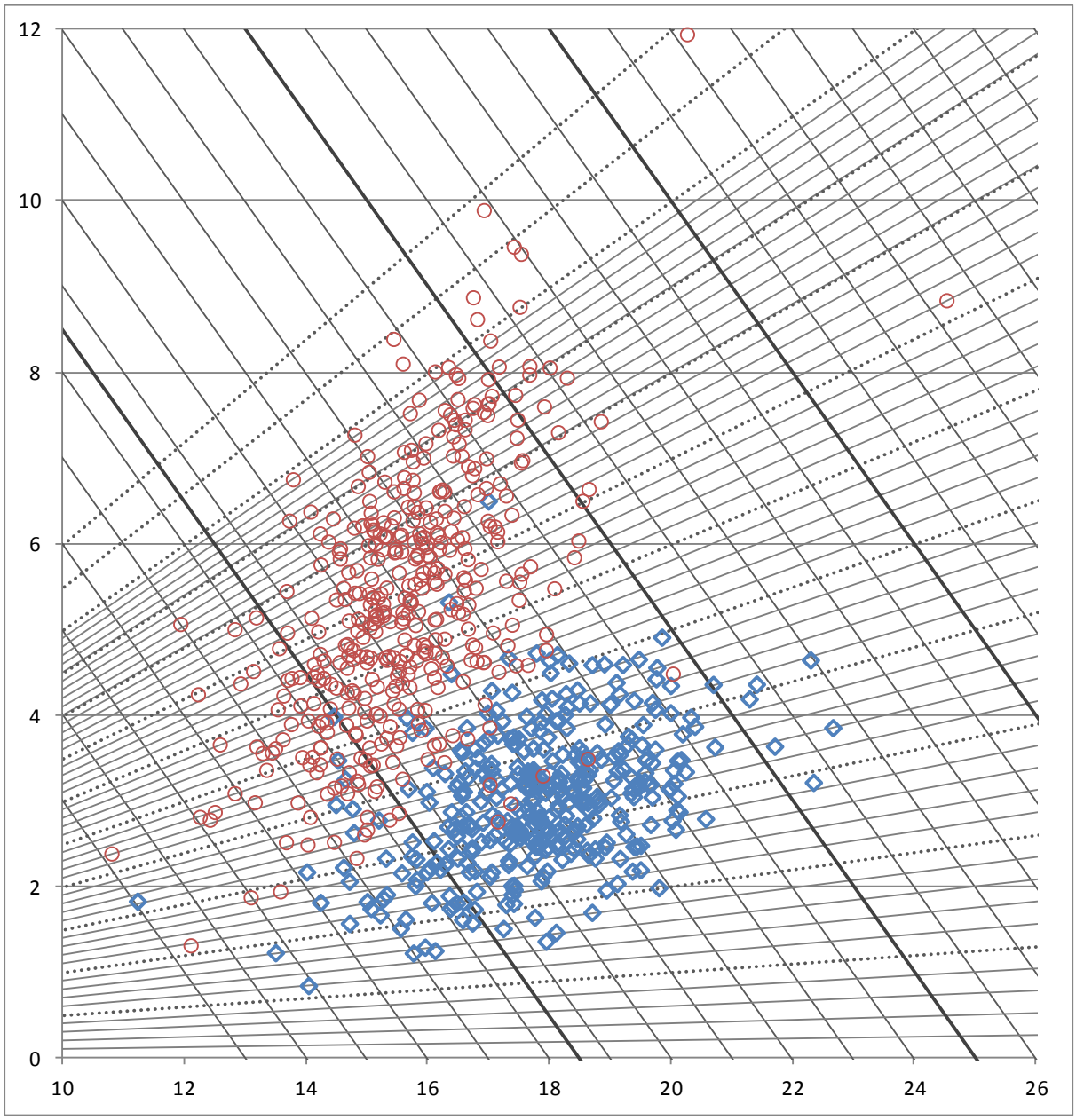

Figure 3: The distribution of BMI and percent body fat of Baka adults on the body composition chart (Blue squares means males and red circles means females).

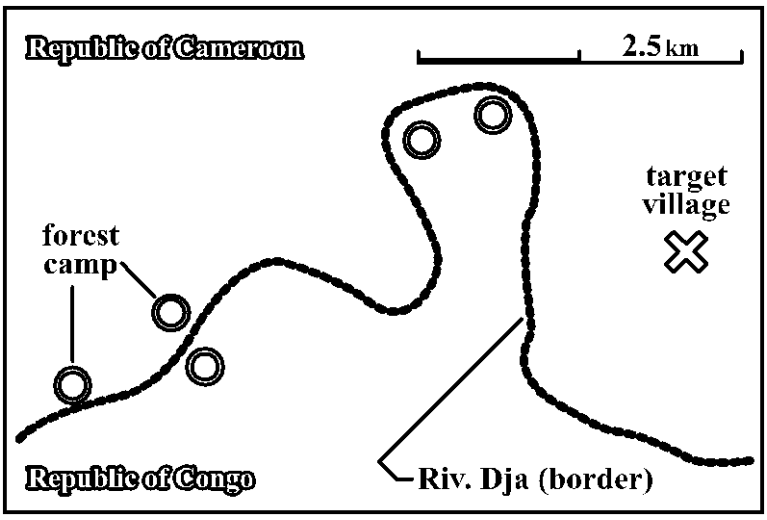

Figure 1: The locations of the forest camps around the target village in 2010.

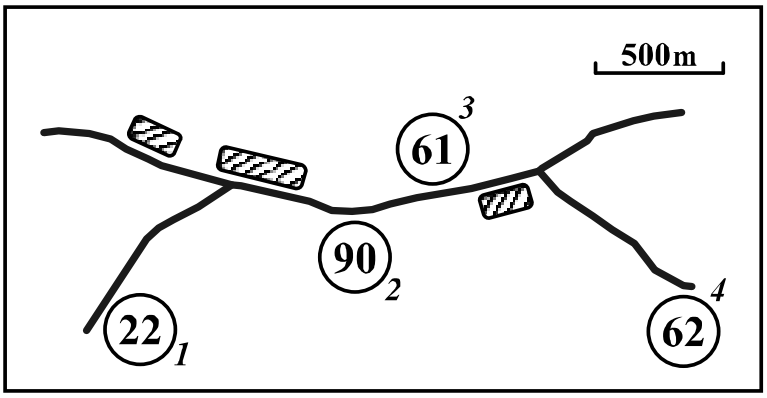

Figure 2: The distribution pattern of residents in the village for 1996.

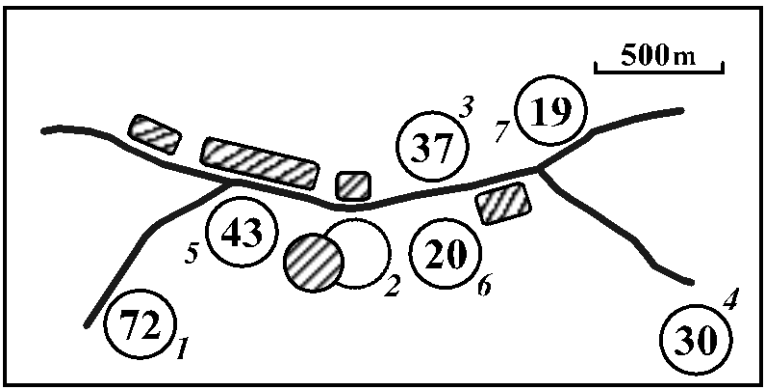

Figure 3: The distribution pattern of residents in the village for 2010.

Table 1: Z-scores for Baka boys.

	1996[1]				2010-2011				*P* [2]
	N	Mean	SD	%Z<-2	n	Mean	SD	%Z<-2	
HAZ	85	-3.05	0.55	98.1	54	-3.39	0.72	95.3	ns
WAZ	87	-2.60	0.92	75.9	54	-3.07	1.14	80.5	ns
WHZ	38	-0.24	0.80	0.0	23	-0.92	1.53	18.4	ns
BMIAZ	85	-0.60	1.10	9.4	53	-0.71	1.05	7.1	ns
UACAZ	88	-0.77	0.54	5.6	54	-0.93	0.68	11.4	ns
TSFAZ	88	-0.80	0.41	0.0	54	-0.60	0.44	0.0	< .05*
SSFAZ	88	-0.10	0.60	0.0	54	0.00	0.70	0.0	ns
AMAAZ	88	-0.25	0.87	0.0	54	-1.36	0.72	19.3	< .0001*
AMAHZ	49	2.26	1.68	0.0	36	0.24	1.46	4.1	< .0001*
AFAAZ	88	-0.86	0.31	0.0	54	-0.77	0.35	0.0	ns
SumSKAZ	88	-0.50	0.47	0.0	54	-0.35	0.52	0.0	ns

1: from Hagino et al. (2011).

2: non paired t-test.

Table 2: Z-scores for Baka girls.

	1996[1]				2010-2011				*P* [2]
	N	Mean	SD	%Z<-2	n	Mean	SD	%Z<-2	
HAZ	64	-3.25	0.69	94.0	50	-3.05	0.93	89.1	ns
WAZ	65	-2.42	1.04	72.0	50	-2.40	1.18	61.5	ns
WHZ	21	-0.03	1.05	0.0	25	-0.32	0.88	9.5	ns
BMIAZ	64	-0.33	0.87	2.1	48	-0.41	0.81	3.1	ns
UACAZ	66	-1.04	0.72	6.0	50	-0.92	0.62	3.0	ns
TSFAZ	66	-0.91	0.64	0.0	50	-0.92	0.50	0.0	ns
SSFAZ	66	-0.13	0.63	0.0	50	0.00	0.49	0.0	ns
AMAAZ	66	-0.57	0.88	6.0	50	-0.28	0.89	1.5	ns
AMAHZ	39	1.34	1.40	0.0	32	1.31	1.25	0.0	ns
AFAAZ	66	-0.88	0.51	0.0	50	-0.86	0.42	0.0	ns
SumSKAZ	66	-0.54	0.60	0.0	50	-0.47	0.49	0.0	ns

1: from Hagino et al. (2011).

2: non paired t-test.

Table 3. Biological parameters about child growth from PB-1.

		Boys			Girls		
		2010-2011	1996 [6]	2010 [7]	2010-2011	1996 [6]	2010 [7]
ATO [1]	(yrs old)	10.70	11.31	10.67	9.75	9.23	9.30
APHV [2]	(yrs old)	14.47	15.19	14.98	12.82	12.17	12.24
AD [3]	(years)	3.77	3.88	4.31	3.07	2.94	2.94
VTO [4]	(cm/yr)	4.04	3.54	3.80	4.24	4.61	4.46
PHV [5]	(cm/yr)	4.56	6.98	4.88	5.47	4.98	4.71

1: Age at take-off.

2: Age at peak height velocity.

3: Adolescence duration.

4: Velocity at take-off.

5: Peak height velocity.

6: from Hagino et al. (2011).

7: from Hagino et al. (2013), large sample study.

Table 4. Anthropometric characteristics of Baka adults.

		Male			Female		
		1996 [4]	2010-2011	*P* [5]	1996 [4]	2010-2011	*P* [5]
N		75	60		73	66	
Height	(cm)	154.4 ± 6.0	152.7 ± 5.7	ns	146.8 ± 5.7	146.8 ± 5.1	ns
Weight	(kg)	49.6 ± 6.2	48.3 ± 7.3	ns	45.1 ± 7.3	45.1 ± 6.6	ns
UAC [1]	(cm)	25.9 ± 1.9	25.6 ± 2.3	ns	24.5 ± 2.3	24.5 ± 2.2	ns
BMI [2]	(kg/m^2)	20.8 ± 1.9	20.6 ± 2.2	ns	20.9 ± 2.2	20.9 ± 2.4	ns
%fat [3]	(%)	13.6 ± 2.9	13.9 ± 2.9	ns	24.3 ± 5.2	25.2 ± 7.8	ns

1: Upper arm circumference.

2: Body mass index.

3: Percent body fat.

4: from Yamauchi et al. (2000).

5: non paired t-test.

Table 5. The number and proportion of BMI classifications for Baka adults.

	Male				Female			
	1996[1]		2010-2011		1996[1]		2010-2011	
Normal	66	88.0%	48	80.0%	59	80.8%	52	78.8%
Thin	7	9.3%	9	15.0%	11	15.1%	11	16.7%
Overweight	2	2.7%	3	5.0%	3	4.1%	3	4.5%
Obesity	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Classified by using cutoffs of WHO (2000).

1: from Yamauchi et al. (2000).

Table 6. The number of *de facto* & *de jure* population in this village

Survey year	Research periods (days)	Num. *de facto* [1]	Num. *de jure* [2]	Ratio[3]
1996	14	238	≈ 238	95.0% <
2010	13	175	214	81.8%
2011	9	128	221	57.4%

1: Number of *de facto* population.

2: Number of *de jure* population.

3: Num. *de facto* / Num. *de jure* (%).

Chapter IV-1

Figure 1: GPS units

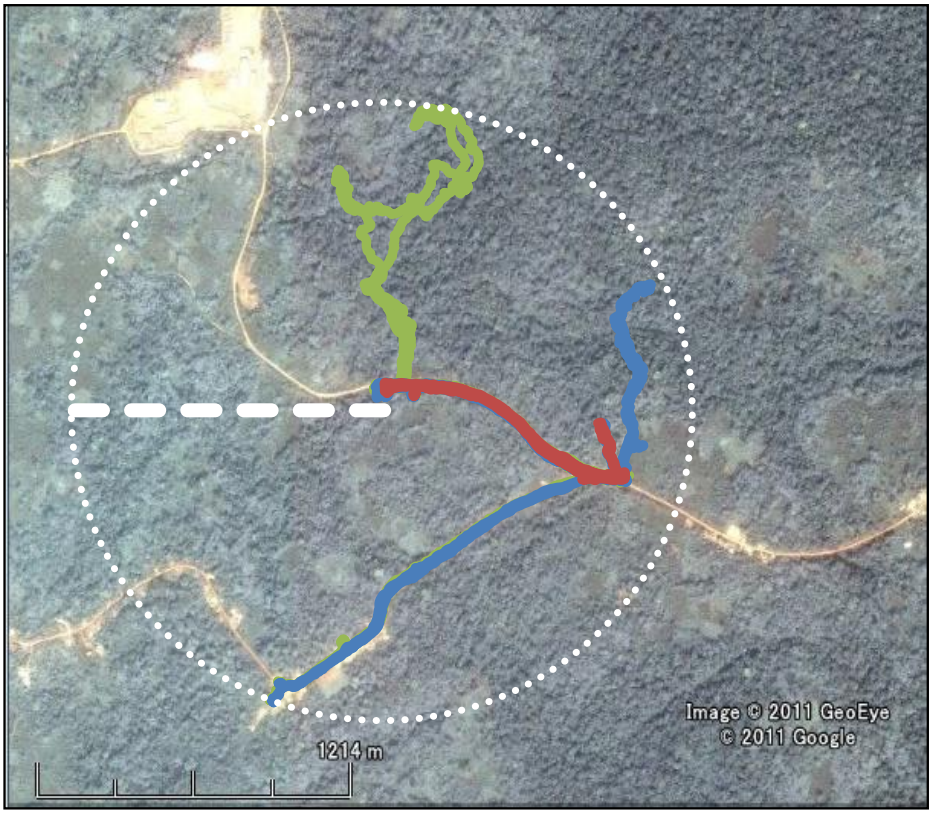

Figure 2: Daily travel route (solid lines) and active radius (dotted straight line). three colors of solid lines means each route of three days (day 1: blue, day 2: green, and day 3: red).

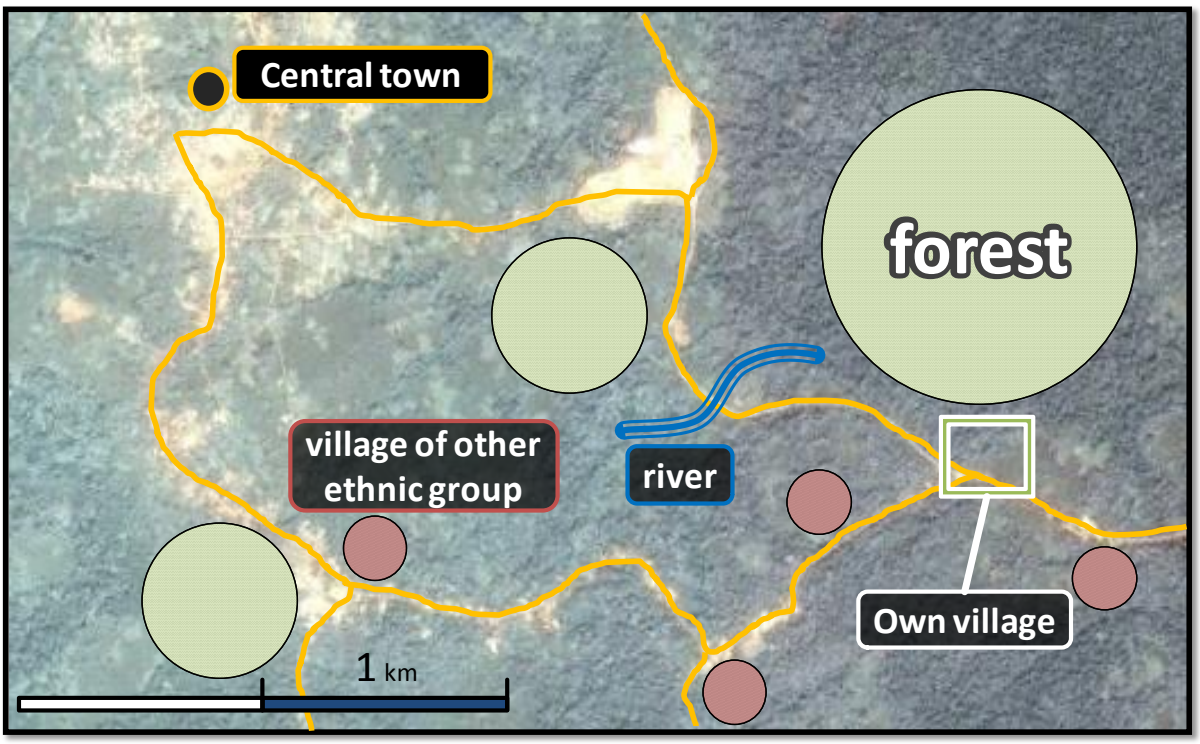

Figure 3: Map for wide area around the target village. River and central town are located for each 900 m and 5 km from the village. Forest are surrounded, and agriculturists' village are dotted nearby the target village.

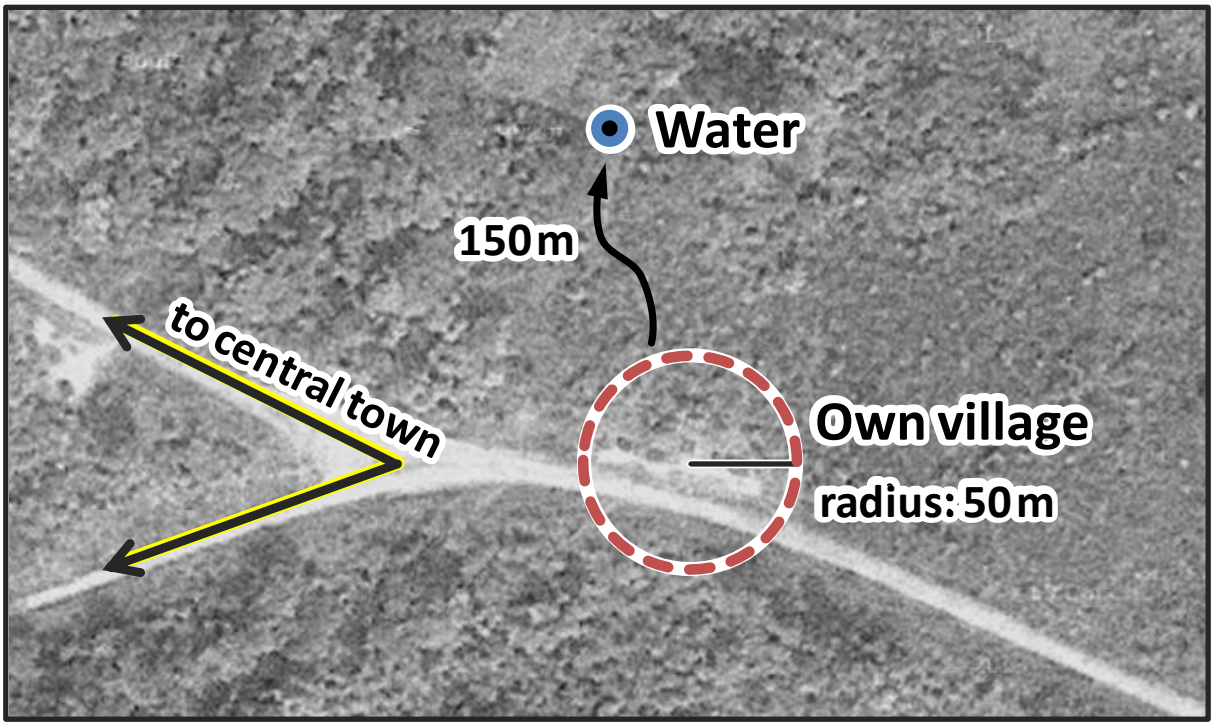

Figure 4: Map for surroundings of the village. Own village were defined as area circled by dotted line, and the radius (solid line) was about 50 m. Water was located about 150 m from the center of village.

Figure 5: Daily travel distances (TDs) for boys. As their age increased, TDs were become longer significantly (N = 61, r = 0.52, $P < 0.0001$)

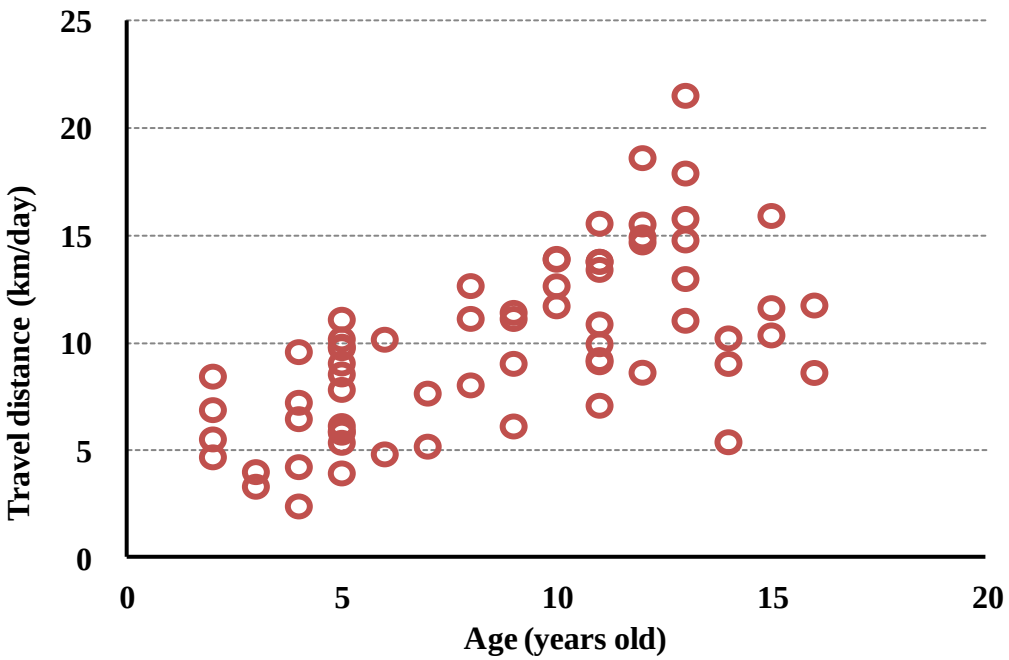

Figure 6: Daily travel distances (TDs) for girls. As their age increased, TDs were become longer significantly (N = 66, r = 0.63, $P < 0.0001$)

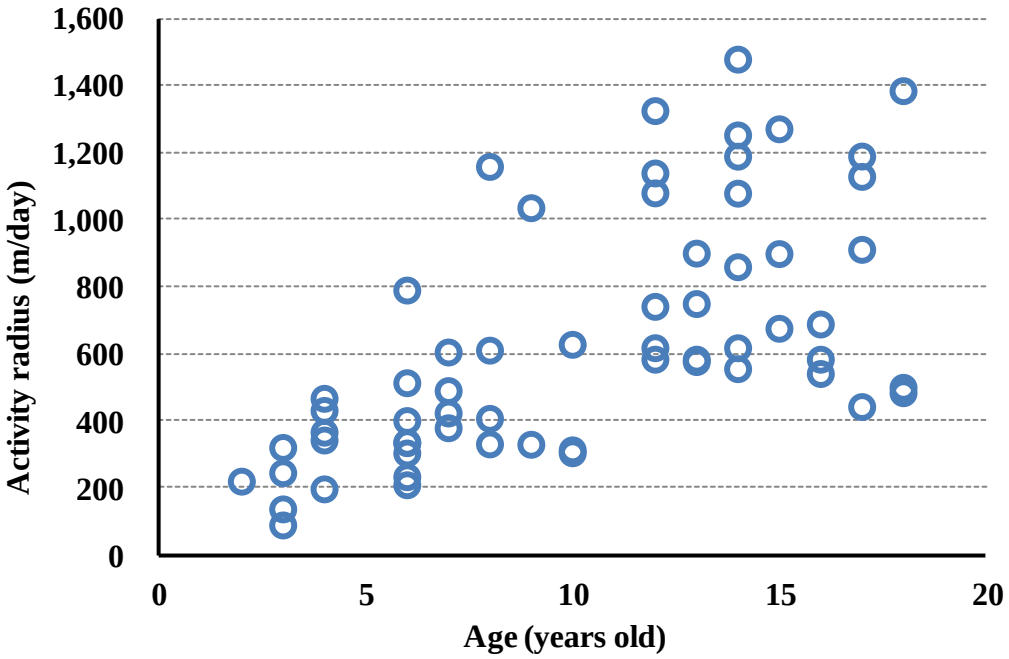

Figure 7: Activity Radii (ARs) for boys. As their age increased, ARs were become greater significantly (N = 61, r = 0.63, $P < 0.0001$)

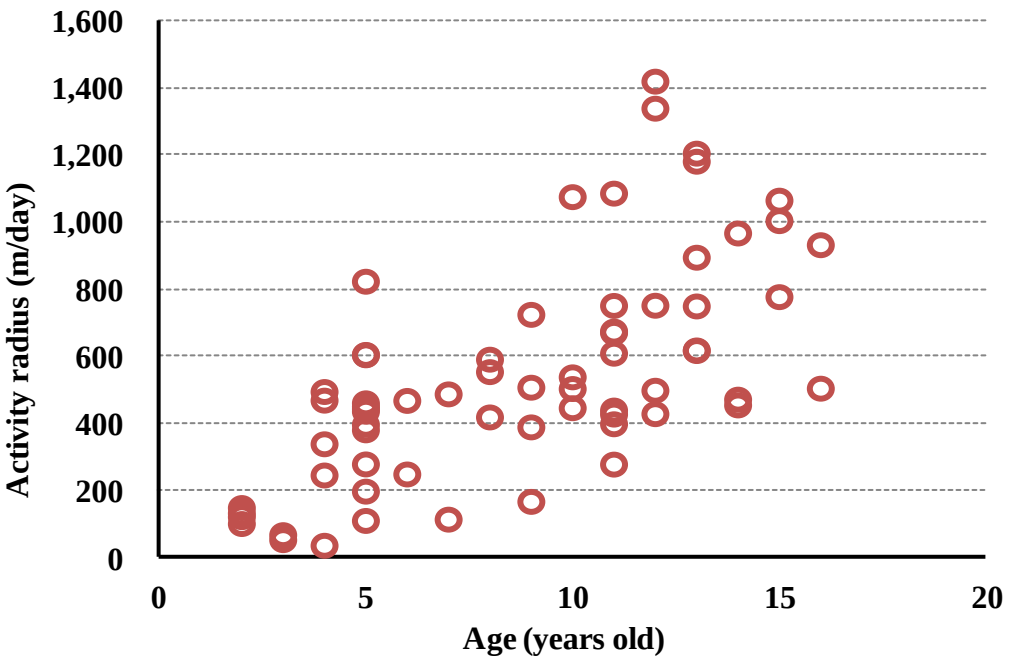

Figure 8: Activity Radii (ARs) for girls. As their age increased, ARs were become greater significantly (N = 66, r = 0.66, $P < 0.0001$)

Table 1: Physical activities of participants

		Boys				Girls				*P*	Males				Females				*P*
		N†	Mean	±	SD	N†	Mean	±	SD		N†	Mean	±	SD	N†	Mean	±	SD	
Steps	(steps/day)	97	25,058	±	8,804	108	23,919	±	6,917	ns	63	13,371	±	7,705	57	14,764	±	8,479	ns
PAL[1]		97	2.05	±	0.24	108	2.02	±	0.21	ns	63	1.66	±	0.21	57	1.74	±	0.24	ns
TD [2]	(km/day)	178	11.5	±	5.4	196	10.0	±	4.7	< 0.01	76	9.3	±	5.7	68	9.7	±	5.2	ns
AR [3]	(m/day)	178	642	±	500	196	545	±	463	ns	76	867	±	784	68	838	±	625	ns

1: Physical activity level

2: Travel distance per day

3: Activity radius per day

†: person-days

non-paired t-test, ns: no significant difference ($P \geq 0.05$)

Table 2: Classifications of steps and PAL of children

		Boys	Girls	*P*
Total		97	108	
steps [1]	over	91	102	ns
	under	6	6	
PAL [2]	vigorous	51	69	ns
	moderate	45	36	
	light	1	3	

1: reference from Tudor-Locke et al. (2004).

2: reference from FAO (2004).

χ^2- test, ns: no significant difference ($P \geq 0.05$)

Table3: The correlation's coefficients between among steps, PAL, TDs, and ARs.

r (N)	steps	PAL	TDs	ARs
steps	-	0.90** (97)	0.85** (95)	0.50** (95)
PAL	0.75** (108)	-	0.73** (95)	0.40** (95)
TDs	0.81** (107)	0.59** (107)	-	0.66** (178)
ARs	0.44** (107)	0.27* (107)	0.66** (196)	-

above: boys, below: girls

*: $P < 0.001$, **: $P < 0.0001$

Table 4: Daily time allocation for 6 areas among Baka children and adults.

	1C		2J		3A		4Y		*P*			5A	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls				Males	Females
N	15	15	16	15	17	22	13	14	Sex	Age	Sex×Age	27	24
Own village	1319	1329	1208	1199	979	1114	1030	1051		****		1118	1137
Forest	67	67	102	126	176	171	152	243		****		210	203
River	21	4	61	52	46	39	58	18	*	**		13	5
Water	11	11	19	25	12	19	13	14				3	14
Other villages	1	26	30	17	182	74	136	68	***	****	***	52	40
Miscellaneous	21	3	20	22	45	24	51	46		*		42	41

Two-way ANOVA.

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$, ****: $P < 0.0001$

1C: Childhood

2J: Juveniles

3A: Adolescence

4Y: Youth

5A: Adult

Table 5: Correlation's coefficients among physical activity factors and travel durations of children.

	Step	PAL	TD	AR
n	69	69	127	127
Own village (total)	-0.60 ****	-0.38 **	-0.83 ****	-0.78 ****
Own village (awake)	-0.31 **	0.10 ns	-0.44 ***	-0.41 ***
Own village (sleep)	-0.50 ****	-0.67 ****	-0.53 ****	-0.34 **
Forest	0.45 ***	0.19 ns	0.60 ****	0.66 ****
River	0.05 ns	0.09 ns	0.22 *	0.11 ns
Water	-0.18 ns	0.05 ns	-0.12 ns	-0.13 ns
Other villages	0.41 ***	0.29*	0.62 ****	0.51 ****
Miscellaneous	0.12 ns	0.13 ns	0.37 ****	0.38 ****

Pearson's correlation's coefficients

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$, ****: $P < 0.0001$

ns: no significant difference ($P \geq 0.05$)

1: person-days

2: n = 68 in vs. Own village (awake) and Own village (sleep).

3: Total time of Own village (awake) and Own village (sleep).

Chapter IV-2

Table 1: Daily time allocation for 11 categories' of activities among 16 children.

	Younger						Older						*P*		
	Boys			Girls			Boys			Girls					
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD	Sex	Age	Sex×Age
Hunting/Fishing	142	±	104	151	±	168	177	±	75	222	±	66			
Gathering	1	±	1	28	±	24	12	±	15	5	±	6			*
Travelling (Forest)	25	±	3	36	±	27	118	±	60	67	±	36		**	
Travelling (River)	9	±	16	25	±	11	2	±	5	52	±	34	**		
Household	28	±	13	37	±	34	69	±	37	45	±	14			
Personal	31	±	16	25	±	24	10	±	12	15	±	10			
Sleeping	17	±	14	29	±	24	33	±	33	6	±	7			
Resting	180	±	55	202	±	94	224	±	51	229	±	25			
Playing	176	±	97	138	±	72	71	±	21	78	±	42		**	
Strolling	33	±	17	31	±	10	3	±	6	3	±	5		***	
Accompanying	81	±	91	20	±	7	2	±	5	0	±	0			

Two-way ANOVA

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$

Table 2: The time allocated for hunting, fishing, and gathering activities.

	Younger		Older	
	Boys	Girls	Boys	Girls
Bail fishing	0	64	15	90
Line fishing	110	11	23	7
Poisson fishing	0	0	0	56
Food gathering	1	21	12	5
cash crop gathering	0	7	0	0
Rat hunting	32	63	139	69
Small game hunting[1]	0	13	0	0
Total	142	189	179	227

1: including pangolins and tree hyraxes

Table 3: The weight of food brought into the camp during each research period.

Category	English name (Baka name)	Num	Total fresh (grams)	Mean of fresh game (g / individual or time)
Mammals	giant poached rat	23 [a]	18,075	904
	giant poached rat	3 [c]	(1,130) [c]	(377) [c]
	tree hyrax	3 [a]	7,322	2,441
	Thomas's dwarf Galago	1 [a]	236	236
Reptiles	Gabon viper	2 [a]	6,800	3,400
	serpent (*seve*)	1 [a]	96	96
	tortoises (*kunda*)	9 [a]	12,532	1,392
	tortoises (*rende*)	1 [a]	539	539
Honey	stingless bee	1 [a]	787	787
Fish	carp (*denge*)	- [b]	12,832	221
	carp (*pede*)	- [b]	279	25
	carp (*sanjange*)	- [b]	220	20
	carp (*fusa*)	- [b]	18	5
	catfish (*bakaa*)	- [b]	4,936	159
	catfish (*lentia*)	- [b]	2,706	69
	catfish (*bose*)	- [b]	1,207	67
	catfish (*motonbi*)	- [b]	410	26
	catfish (*bokao*)	- [b]	129	32
	tadpole	- [b]	587	19
Crustaceans	crabs	- [b]	3,711	93
	shrimps	- [b]	498	19
Mollusc	African snail	9 [a]	1,267	141
Insects	termites	4 [a]	122	31
Wild Yam	wild yam (*ba*)	2 [a]	5,530	2,765
	wild yam (*ndondo*)	1 [a]	280	280

a: Numbers of individuals or times

b: brought back within a bowl, thus the individual weight were not weighed.

c: brought back after cut into various parts.

Table 4: The energy and protein content from obtained food resources.

	Energy (kcal)	Protein (grams)	Energy (%)	Protein (%)
Children	23,081	3,406	31.0	32.5
Cooperation (children - adults)	16,099	2,054	21.6	19.6
Adults	35,238	5,030	47.4	48.0
Total	74,418	10,490	100	100

a: Calculated using food composition tables from Leung (1968) and Ministry of Education, Culture, Science and Technology, Japan (2005)

b: Percentages of total energy or protein

Figure 1 : A giant pouched rat (about 400-1,200 grams).

Figure 3 : A small Thomas's dwarf galago (236 grams).

Figure 2 : A tree hyrax (about 800-3,600 grams).

Figure 4 : A Gaboon viper (about 3,000-3,500 grams).

Figure 5 : A tortoise (about 500-2,000 grams).

Figure 6 : Aquatic fauna (fish and crustaceans).

Figure 9 : A child playing by hanging on a vine.

Figure 7 : Wild yam tubers (about 3,300 grams of tubers are in a pot).

Figure 10 : Girls playing in the center of the camp.

Figure 8 : Honey.

Figure 11 : An adolescent girl taking care of her brother and infant sister.

Figure 12 : A child playing with bows and arrows.

Figure 13 : A child feeling inside of a burrow.

Figure 14 : Children stuffing the tunnel with dry leaves, setting fire, and smoking out the rats.

Figure 15 : Younger children line fishing.

Figure 16 : A group of girls bail fishing.

Figure 19 : Children removing the water using leaves.

Figure 17 : A 20-30 cm height of soil wall that was constructed to hold back a shallow river temporarily.

Figure 20 : The soil wall collapsed and the water flow returned to as it was.

Figure 18 : Children digging the clods that they push into the river.

Figure 21 : Children scraping the mud off of fish and classifying them by species.

Figure 22 : A boy tried to climb the tree; however, the foothold was unsuitably high, and the wood string was not well adjusted.

Figure 23 : A male adult sets an example for boys by climbing a tree.

Conclusion

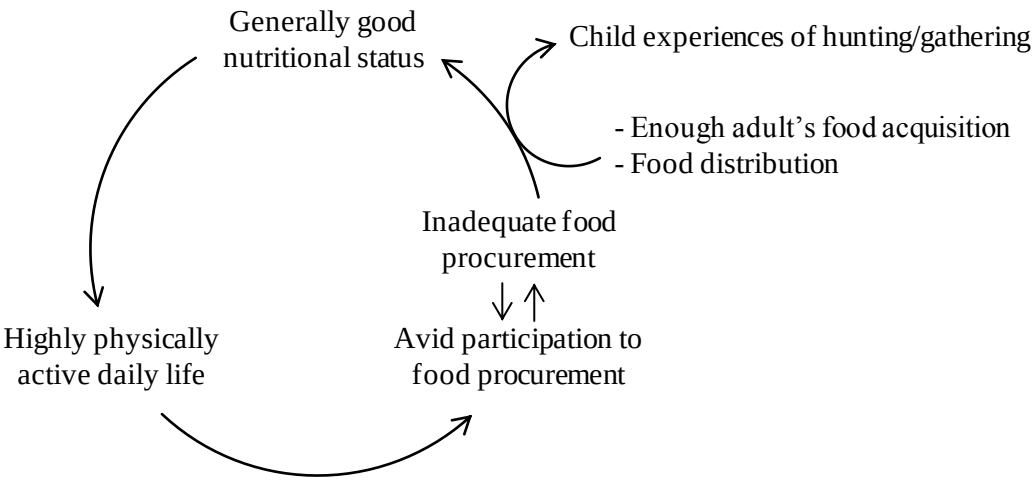

Figure 1: The ecological system among Baka children.