Growth and Nutritional Status of Tonga Children in Rural Zambia
-Longitudinal Growth Monitoring over 26 Months-

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Abstract

Objective: This study aimed to evaluate growth and nutritional status of children in rural Zambia by analyzing 26 months of longitudinal data on height and body weight data, with a special emphasis on sex and age differences.

Participants and Methods: Participants were 218 children (106 boys, 112 girls) from 48 households. Between November 2007 and December 2009, height was measured monthly and body weight was measured weekly. Weekly body weight was averaged over each month. Body mass index (BMI) was calculated using the height and body weight. Growth curves of height and body weight were drawn for each sex using all data measured over the 26-month period, and were evaluated against percentile curves of the National Center for Health Statistics (NCHS) reference population. Nutritional status was assessed using calculated Z-scores, and the rate of malnutrition such as stunting (low height-for-age Z-score), underweight (low weight-for-age Z-score), wasting (low weight-for-height Z-score), and thinness (low BMI-for-age Z-score) were determined.

Results and Discussion: Similar to the results of previous studies in Zambian children, the rate of stunting was high. However, based on the BMI Z-score or the weight-for-height Z-sore where influences of height and weight are offset, it is suggested that nutritional status of these children is generally good. Distinct variations in nutritional status by age were observed in the children, and were possibly due to the approximately 2-year delay of puberty compared to the reference US population. Further studies are needed to assess nutritional status comprehensively by examining the children's diet and physical activity in addition to anthropometry. It would be desirable to develop local reference growth curves instead of using international reference data based on Western populations in order to evaluate growth and nutritional status of the Zambian children adequately.

1. Introduction

Child growth is an important, internationally recognized public health indicator for monitoring nutritional status and health in populations (de Onis and Blössner 2003). From an ecological viewpoint, environmental changes in an ecosystem affect the conditions of fauna and flora, which consequently cause a decrease in body weight and body fat in general and growth retardation in children, through decreasing food availability and nutritional intake among the local

population.

Multiple factors affect the nutritional status of children including dietary intake, infection, breast feeding and weaning, seasonality, and socio-economic status (Waterlow 1992). Malnutrition in childhood increases the risks for infectious diseases (Waterlow 1992), cardiovascular disease in adulthood (Stein et al. 2006), and lower mental development (Grantham-McGregor 1995), as well as reduce work capacity (Thomas et al. 2002). It is thus important to assess and ensure adequate nutritional status and growth in children.

In October 2007, we started a longitudinal survey to monitor the growth and nutritional status of local people living in five villages located in the Sinazongwe district in the Southern province of Zambia (Yamauchi et al. 2008). We have reported the nutritional status of adults and children, as well as the growth status of children, in the initial stages of a longitudinal survey of people living in three ecologically contrasting zones: the upper flat land zone on the plateau, the middle slope zone, and the lower flat land zone near Lake Kariba (Yamauchi 2009), and variation in the nutritional status of adults (Yamauchi and Kon 2010).

In this study, we report the results of nutritional status and growth evaluation in children following analysis of 26 months of longitudinal data of monthly height and weekly body weight data obtained between November 2007 and December 2009, with a special emphasis on sex and age differences.

2. Subjects and Methods

2.1 Study populations and subjects

The slope area around Lake Kariba can be divided into three ecological zones: the upper flat land zone on the plateau ('upland'), the middle slope zone ('hillside') and the lower flat land zone near Lake Kariba ('lowland') (Sakurai 2008). We chose five villages in the area: two (Sianemba and Siameja) from the lower zone, two (Chanzika and Kanego) from the middle zone, and one (Siachaya) from the upper zone. Forty-eight households were selected, 16 from each of the three zones: 4 in Sianemba, 12 in Siameja, 8 in Chanzika, 8 in Kanego, and 16 in Siachaya.

The anthropometric data of 218 children (106 boys, 112 girls) from the 48 households were analyzed. Height data were available for 213 individuals (103 boys, 110 girls), while weight data were available for 212 (101 boys, 111 girls), with both height and weight data available for 207 children (100 boys, 107 girls) (cf. Table 1, total number of stunting [height], underweight [weight], thinness [height and weight]).

2.2 Anthropometric measurements

Details of the anthropometric measurements are given elsewhere (Yamauchi et al., 2008). Briefly, height was measured monthly to the nearest 1 mm using a portable stadiometer (SECA 214, Germany). Body weight was measured weekly to the nearest 0.1 kg using battery-operated digital scales (Tanita HD-654, Japan). Weekly body weight was averaged over each month. The body mass index (BMI) was calculated using the height and body weight for each subject.

2.3 Growth curves

Growth curves of height and body weight were drawn for each sex using all data obtained between November 2007 and December 2009. The total height data obtained monthly amounted to 1473 and 1362 for boys and girls, respectively. The total data of body weight (monthly averaged) amounted to 1493 and 1579 for boys and girls, respectively. The growth curves were drawn on the percentile curves of the National Center for Health Statistics (NCHS) reference population, which is commonly used for the evaluation of growth and nutritional status (Hamill 1977, Frisancho 1990).

2.4 Nutritional status

Using NCHS reference data, the measured values were standardized. The formula for calculating the Z-score is:

Z-score = (observed value - median reference value) / standard deviation of reference population

There are four Z-scores which are commonly used for assessing nutritional status of children, where malnutrition is defined by a Z-score below -2.

Height-for-age Z-score (HAZ) < -2: 'Stunting'

Weight-for-age Z-score (WAZ) < -2: 'Underweight'

Weight-for-height Z-score (WHZ) < -2: 'Wasting'

BMI-for-age Z-score (BMIAZ) < -2: 'Thinness'

The sex-age specific rate of malnutrition was determined for the four indices of 'stunting', 'underweight', 'wasting', and 'thinness'.

3. Results and Discussion

3.1 Growth curves

Figures 1 and 2 show the height and weight growth curves, respectively, of the study population against the percentile curves of the US NCHS reference population (Hamill et al. 1977, Frisancho 1990). Compared to the reference population, the Zambian children were short and light. The age-sex−specific mean values of height and weight corresponded to lower percentiles (i.e., 5th −15th percentiles) before puberty, declined 5 percentiles after onset of puberty, and recovered to the pre-puberty level at the end of puberty.

As for the height growth curves, the age-specific mean values were between the 5th and 15th percentiles of the reference curves for both boys and girls from 1 - 11 years old, except for 10-year-old girls. After 11 years, the mean height was decreased below the 5th percentile, before rising to reach the 10th percentile at 16 years of age in girls (Fig. 1B) but remaining below the 5th percentile in boys (Fig. 1A). As to body weight, boys' mean weight values were on the 10th−15th percentiles curves for age 1 - 10 years (Fig. 2A), before starting to decline at 11 years old and then increased again at 13 years old, reaching the 10th percentile at 17 years old. The body weight of girls, on the other hand, was lower than that of boys (Fig. 2B). The mean weight values were around the 5th percentile for 1 - 7 years old, and weight started to decline after 8 years old and was lower than the 5th percentile of the reference population. Similar to boys, it rose again at 13 years

old, reaching the 10th percentile at 16 years old.

The findings that the growth rates of weight and height declined at the onset of puberty and fell below the 5th percentile curve of the reference population and rose again to recover to pre-puberty levels are discussed later with the results of age variation in nutritional status.

3.2 Nutritional status

Table 1 shows the sex-region−specific rate of malnutrition based on the 4 indices of stunting (low height-for-age), underweight (low weight-for-age), wasting (low weight-for-height), and thinness (low BMI for age). The rate of stunting was relatively high for the malnutrition indices. Previous studies also reports high rate of stunting in Zambian children (Gernaat et al. 1996, Gillett et al. 2002). The rate of underweight was lower than that of stunting. Moreover, the rates of wasting and thinness which consider both height and weight were considerably low for the four malnutrition indices. No children were categorized into some age-region groups. Combining the results for the rate of malnutrition together with those for the growth curve indicate that the nutritional status of Zambian children was generally good even though the children were significantly short and light when compared with the reference age- and sex-matched Western population.

In regard to regional differences, the rate of malnutrition was higher in upland regions and lower in lowland regions. This corresponds to our previous findings that adults living in lowland regions had the largest body size and body mass index (BMI) among the three subgroups (Yamauchi 2009, Yamauchi and Kon 2010). These findings suggest that among the three regional populations, both children and adults living in the lowland regions have relatively good nutritional status. However, since no statistical significant regional difference was observed except in the case of girl's stunting (P < 0.01), the regional subgroups were combined and the relationship between age and nutritional status was examined for boys and girls separately (Fig. 3).

3.3 Age variation in nutritional status

Figure 3 shows the age-specific mean Z-scores of HAZ, WAZ, WHZ, and BMIAZ for boys (Fig. 3A) and girls (Fig. 3B) aged 1 - 17 years. WHZ and BMIAZ were relatively high at -1 - 0 for all ages, whereas HAZ and WAZ were relatively low at -2 - -1. The Z-scores tended to decrease at around 11 years old and increase at around 16 years old for both sexes, which is consistent with the findings of the growth curves for height (Fig. 1) and weight (Fig. 2).

One of possible reasons for this phenomenon is the difference in growth pattern between Zambian children and the reference population (Western children). Previous studies demonstrate that timing of pubertal maturation (onset and end) is later in Zambian rural children than that in Western children: 10.0 - 15.9 and 10.0 - 15.5 years old for US boys and girls, respectively, compared to 12.4 - 17.1 and 13.2 - 17.0 year olds for rural Zambian boys and girls, respectively (Campbell et al. 2004, Gillett-Netting et al. 2004, Herman-Giddens 2006). In other words, the timing of puberty for rural Zambian children is delayed by about 2 years compared with that for US children. This gap in the timing of puberty may cause the variation in Z-scores observed in the Zambian children after onset of puberty (Fig. 3). In agreement with the present study, similar age variation in Z-scores was observed in Zambia (Crooks 2007) and in the neighboring country

Malawi (Zverev and Gondwe 2001), suggesting a common tendency in southern Africa. It is thus recommended that standard growth curves based on a Zambian national sample or Zambian ethnic sample be developed in order to evaluate nutritional status adequately.
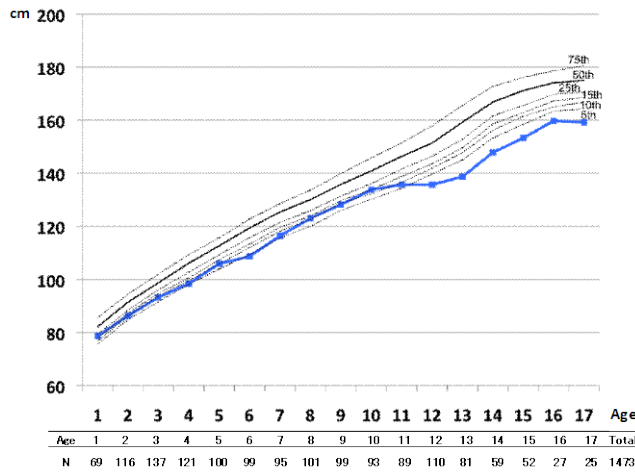
4. Summary and Future Perspective

Similar to the results of previous studies, the rate of stunting (low height-for-age) was high in rural Zambian children. However, according to the Z-scores for BMI or weight-for-height where influences of height and weight are offset, it is suggested that the nutritional status of rural Zambian children is generally good. Distinct age variations in nutritional status were observed in Zambian children, possibly due to the approximate 2-year delay in puberty compared to the reference US population. Further studies are needed to assess nutritional status comprehensively by examining the diet and physical activity of children in addition to anthropometry. It would be desirable to develop local reference growth curves instead of using international reference data based on Western populations in order to evaluate growth and nutritional status of the Zambian children adequately.

Table 1. Rate of malnutrition in rural Zambian children

		Stunting		Underweight		Wasting		Thinness	
		N	%	N	%	N	%	N	%
	Lowland	27	29.6	26	7.7	22	0.0	27	3.7
Boys	Hillside	39	33.3	38	7.9	35	2.9	38	0.0
	Upland	37	37.8	37	16.2	34	2.9	35	2.9
	All	103	34.0	101	10.9	91	2.2	100	2.0
	Lowland	35	14.3	35	0.0	32	0.0	35	0.0
Girls	Hillside	35	31.4	35	14.3	29	3.4	33	0.0
	Upland	40	47.5	41	7.3	34	11.8	39	5.1
	All	110	31.8*	111	7.2	95	5.3	107	1.9

*Significant reginal difference ($P < 0.01$) by Kruskal-Wallis test

A: Boys   B: Girls
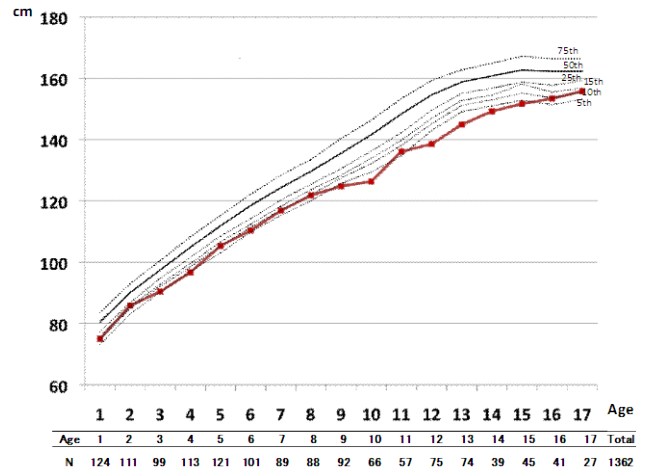

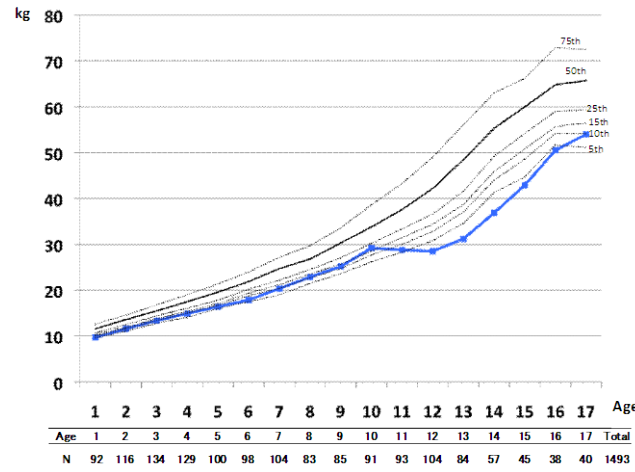Fig. 1. Height growth curves by sex for 1–17 year olds

A: Boys   B: Girls
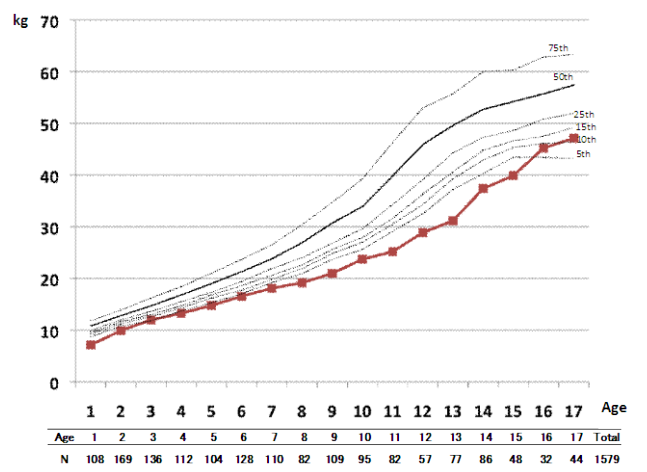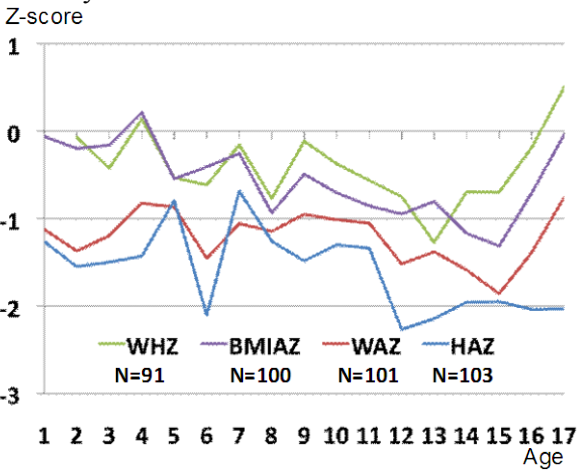

Fig. 2. Body weight growth curves by sex for 1–17 year olds
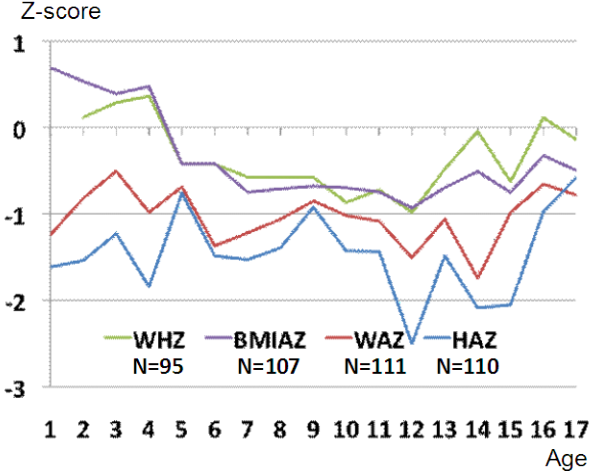
A: Boys   B: Girls

Fig. 3. Nutritional status based on Z-scores by sex for 1–17 year olds

References

Campbell BC, Gillett-Netting R, Meloy M (2004) Timing of reproductive maturation in rural versus urban Tonga boys, Zambia. Ann Hum Biol, 31, 213-227.

Crooks DL, Cliggett L, Cole SM (2007) Child growth as a measure of livelihood security: the case of the Gwembe Tonga. Am J Hum Biol, 19, 669-675.

de Onis M, Blössner M (2003) The world health organization global database on child growth and malnutrition: methodology and applications. Int J Epidemiol, 32, 519-526.

Frisancho AR (1990) Anthropometric Standards for the Assessment of Growth and Nutritional Status. University of Michigan Press, Ann Arbor.

Gernaat HB, Dechering WH, Voorhoeve HW (1996) Physical growth of children under five years of age in Nchelenge, Zambia: results from a district survey. Am J Phys Anthropol, 100, 473-485.

Gillett RM, Tobias PV (2002) Human growth in southern Zambia: a first study of Tonga children predating the Kariba dam (1957–1958). Am J Hum Biol, 14, 50-60.

Gillett-Netting R, Meloy M, Campbell BC (2004) Catch-up reproductive maturation in rural Tonga girls, Zambia? Am J Hum Biol, 16, 658-669.

Grantham-McGregor S (1995) A review of studies of the effect of severe malnutrition on mental development. J Nutr, 123, 2233S-2238S.

Hamill PV, Drizd TA, Johnson CL, Reed RB, Roche AF (1977) NCHS growth curves for children birth-18 years. United States. Vital Health Stat 11, 1-74.

Herman-Giddens ME (2006) Recent data on pubertal milestones in United States children: the secular trend toward earlier development. Int J Androl, 29, 241-246.

Sakurai T (2008) Asset holdings of rural households in southern province, Zambia: a report from census in the study villages. Vulnerability and Resilience of Social-Ecological Systems, FY2007 FR1 Project Report, 185-200.

Stein AD, Wang M, Ramirez-Zea M, Flores R, Grajeda R, Melgar P, Ramakrishnan U, Martorell R (2006) Exposure to a nutrition supplementation intervention in early childhood and risk factors for cardiovascular disease in adulthood evidence from Guatemala. Am J Epidemiol, 164, 1160-1170.

Thomas D, Frankenberg E (2002) Health, nutrition and prosperity: a microeconomic perspective. Bull World Health Organ, 80, 106-113.

Waterlow JC (1992) Protein-Energy Malnutrition, Edward Arnold, London.

Yamauchi T (2008) Training local health assistants for a community health survey in Zambia: Longitudinal monitoring of growth and nutrition of children. Vulnerability and Resilience of Social-Ecological Systems, FY2007 FR1 Project Report, 60-65.

Yamauchi T (2009) Growth and nutritional status of children and adults living in contrasting ecological zones in the southern province of Zambia. Vulnerability and Resilience of Social-Ecological Systems, FY2008 FR2 Project Report, 41-49.

Yamauchi T and Kon S (2010) Variation in the Nutritional Status of Adults Living in Contrasting

Ecological Zones in the Southern Province of Zambia. Vulnerability and Resilience of Social-Ecological Systems, FY2009 FR3 Project Report, 45-52.

Zverev Y and Gondwe M (2001) Growth of urban school children in Malawi. Ann Hum Biol, 28, 384-394.