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Original Article

Body Composition due to Differences in Residential Area and School Meals Provision in Cambodian Children

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Abstract

Background: Cambodia, as a developing country, is classified as a poor country; however, in recent years, rapid economic development has been seen in urban areas and the regional differences between the rich and the poor have been increasing. In addition, school meals have been adopted on a trial basis in rural areas, and efforts are being made to support growth and development in childhood. The purpose of this study was to examine whether differences in residential area and school meals availability have an effect on the body size and composition of schoolchildren.
Methods: The subjects were 3,198 schoolchildren (1,638 boys and 1,560 girls) aged 6 to 11 years old and height, weight, and body composition measurements were taken as a cross-sectional study once a year during the period from 2017 to 2020. Differences among age and schools in residential areas were analyzed via two-way ANOVA ($P<0.05$).
Results: The results of the present work showed that height, weight, and body mass index were clearly higher in urban schools compared to rural schools ($P<0.001$). In terms of body composition, muscle mass and fat-free mass index ($P<0.001$) were higher in urban schools than in rural schools and body fat percentage and fat mass index ($P<0.001$) were 1.5 to 2 times higher in urban schools. On the other hand, in rural areas, fat-free body mass index values were significantly higher in schools with school meal programs ($P=0.001$).
Conclusion: The results shed light on the need for health education not only in terms of undernutrition, but also in terms of overnutrition in Cambodian children.

Keywords: Child, Cambodia, Body composition, School meals, Residential area

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1. Introduction

Currently, rapid increases in the rates of obesity and overweight are widely documented, from urban and rural areas in the poorest countries of Asia to populations in countries with higher income levels (1). The prevalence of overweight and obesity among adult women in urban areas is twice as high as in rural areas in low- and middle-income countries, 37% in urban areas, and 19% in rural areas and it has been shown to be similar in Asian countries (1). It has been reported that lifestyle-related diseases, such as obesity, are becoming more prevalent in developing countries and are thought to be influenced by urbanization, changes in nutritional status, and decreased physical activity brought about by rapid economic development (2, 3). Forty million children are overweight and obese around the world and there has been an increase of 10 million since the year of 2000 (4). The causes of higher rates of obesity likely include extreme and rapid changes in lifestyle, physical activity, and diet that accompany urbanization and rapid economic development. In other words, increased television viewing and decreased exercise time have led to a static lifestyle; thus, high-fat food intake has increased (5). In contrast, stunting is caused by inadequate nutrition or disease and there are approximately 149 million children over the age of five suffering from stunting worldwide (6). In other words, energy deficiency due to poor nutrient intake may cause stunted growth in children and increase their susceptibility to disease. Nutrition and other contributors to health in childhood are important determinants of adult body composition and obesity risk. Therefore, efforts to maintain a healthy nutritional status are important for children's growth and development.

School feeding programs (SFP) have been continuously trialed in developing countries that are severely affected by childhood hunger and malnutrition.

SFP in developing countries are designed to relieve short-term hunger, promote children's growth and development, and improve their ability to concentrate and learn (7). After serving breakfast daily for 8-month-old to elementary school children in rural Jamaica, the results showed that children in the breakfast group had significant increases in body weight, height, and body mass index (BMI) and the body weight gain of the intervention group members was even greater than the height gain, equivalent to two to three months of body weight gain in the control group (8). Similarly, a large study conducted in Bangladesh revealed evidence that SFP in food insecure rural and slum areas positively impact school age children's dietary intake and educational outcomes (9). In addition, the children that were fed gained body weight of about 0.4 kg (10%) more than the control children in Kenya and in terms of body composition, the average brachial circumference, used as an indicator of protein-energy malnutrition, and the middle brachial muscle circumference, an index of the total body muscle mass, also increased compared to the control group, respectively (10).

However, in many developing countries, the concept of preventive medicine is not nationally recognized and there is not only insufficient physical data on children for health education but also no measurement system. Indeed, most of these countries do not show an effective growth standard or body composition data in their children. In addition, there are large regional differences in the growth and development of children in Cambodia, the target country of this paper, due to the large gap between the rich and poor areas (11). To solve this problem, school meals provision was trialed in some rural areas; however, its effect on growth and development in Cambodian children has yet to be investigated. The present study aimed to compare primary school children's growth and body composition in three different contexts: an urban school, a rural school with "school meals", and a rural school without "school meals" in Cambodia.

2. Methods

Aichi University of Education in Japan collaborated with the National Institute of Education in Cambodia to conduct a study on the physical child growth of some primary school students in Cambodia from 2017 to 2020. We performed all the measurements as an annual cross-sectional study. The number of subjects measured was shown by sex and schools of residence (Table 1). Five-to-twelve-year-old healthy Cambodian children were measured for cross-sectional data of the body composition study in each primary school of Cambodia. We verified the consent to participate, sex, the date of birth, and age through Khmer interpreters for all the students attending school on the measurement day. In addition, the date of birth was reconfirmed through the class list (Total 3,506 children). We excluded children who were up to 5 years old and older than 12 years old since the present study included primary school-aged children in addition to other children with missing data for the exposure and outcome variables (195 children). Therefore, the study population consisted of 3,311 children (1,693 boys and 1,618 girls) between the ages of 6 and 11 years.

Our study was designed to investigate the physical growth of school-age children over different geographical and socioeconomic areas in Cambodia. In the following descriptions of this paper, the schools are indicated by tentative names (A to D) in no particular order. Phnom Penh, where a primary school (School A) is located, is the capital of Cambodia and is considered a region of high socioeconomic status. Siem Reap, where B primary school (School B) is located, is a tourist town where the income of the people living in the tourist site is much higher than those living in rural areas. The area where C and D primary schools (School C and School D) are located is a swampy plain where most people work as farmers and most people's lives are poorer than in urban areas. The World Food Program (WFP) has been providing nutritious school meals for certain primary schools located in rural areas. WFP's School Meals Program provides a nutritious breakfast to all students in the school prior to class. School C, for which WFP provides school meals, was selected from more than 7,000 public primary schools in Cambodia. The schools with "school meals" in this study are those provided with a nutritious breakfast for all children

Table 1: A breakdown of the children per location between 2017 and 2020

School	Classification	School meals	Boys	Girls	Total
A	Uban	Not	528	543	1,071
B	Uban	Not	468	452	920
C	Rural	Provided	340	306	646
D	Rural	Not	357	317	674
		Total	1,693	1,618	3,311

while other schools are not provided with school meals.

The measurement method was devised so that it could be implemented locally since this study was conducted as part of health education support; hence, the measurement tools of height and body weight used in this study were daily life equipment that can be purchased from markets in Cambodia. Most of the methods in the present work follow the methods of the study we have already reported (11).

First, children listened to the precautions during the measurement as explained by the examiner and understood the details of the measurement. Afterwards, we verified their date of birth and age through Khmer interpreters. Each participant received his/her information sheet to be used in the measurement station. The children's details were measured in the following order: height, weight, and body composition. Height measurements were taken as follows: Step 1, a schoolchild was asked to remove his/her shoes, socks, and any relevant items worn on the head; Step 2, they were asked to stand still with both their feet on the footprint; Step 3, they were asked to stand tall with their back against the wall and feet together and we ensured that the head, buttocks, and heels were touching the wall as much as possible; Step 4, the subject was asked to look straight ahead; Step 5, the research team placed the right triangle gently and firmly on the subject's head and pressed it against the wall; and Step 6, the research team read the measurement paralleled with the right triangle and recorded the measurement to the nearest 1 mm (0.1 cm) on the information sheet.

Body weight measurements were taken as follows: Step 1, a schoolchild was asked to remove his/her shoes, socks, and any relevant items on his/her body except for light clothing; Step 2, we asked the schoolchild to stand still with both feet on the footprint; Step 3, the research team read the display on the scale screen and recorded the measurement to the nearest 100 g (0.1 kg) on his/her information sheet. BMI (kg / m^2) was calculated as body weight / height^2.

We measured body composition using a Japanese multi-frequency bioelectrical impedance analyzer (BIA, TANITA RD-800, Japan) and calculated muscle mass (kg) and body fat percentage (%). Fat-free mass (FFM, kg) was then calculated as the difference between body weight and fat mass (FM, kg). Both FFM and FM were divided by stature^2 to give FFMI (Fat-free mass index) and FMI (Fat mass index, BMI=FFM, kg / height, m^2+FM, kg / height, m^2). These two component indices are known as the FFM index (FFMI, kg/m^2) and FM index (FMI, kg/m^2), both being discrete and adjusted for body size.

SPSS software version 27 (IBM, Japan) was employed for the statistical analysis. The results were presented as mean±standard deviation (SD). Differences among age and schools in residential areas were analyzed via two-way ANOVA. When overall differences were considered to be significant with ANOVA, post hoc comparisons were performed with the Bonferroni test.

Table 2: Results of descriptive statistics of anthropometric measurements

	Age, yr	Boys			Girls		
		n=1693	Mean	SD	n=1618	Mean	SD
Height, cm	6	248	113.4	5.5	262	112.5	5.4
	7	255	117.9	6.2	215	117.9	5.3
	8	271	123.0	6.5	276	122.9	6.0
	9	308	127.8	6.8	275	128.2	6.9
	10	321	132.4	7.4	321	133.8	7.4
	11	290	137.9	8.2	269	139.5	8.4
Body weight, kg	6		19.3	3.2		18.8	3.3
	7		21.5	4.8		20.8	3.8
	8		23.8	5.0		23.3	4.8
	9		26.5	6.2		25.9	5.7
	10		29.7	7.8		29.9	8.1
	11		32.9	9.0		33.7	8.8
Body mass index, kg/m^2	6		14.97	1.54		14.81	1.87
	7		15.33	2.25		14.92	1.90
	8		15.61	2.02		15.34	2.22
	9		16.04	2.47		15.67	2.38
	10		16.74	2.86		16.51	3.09
	11		17.04	3.02		17.11	3.12

The differences at $P<0.05$ were considered significant. The current work was carried out in compliance with the Declaration of Helsinki, the Ethical Guidelines for Clinical Research, and the Act on the Protection of Personal Information. We then structured and checked our paper using the "STROBE Statement-Checklist of cross-sectional studies" (12).

3. Results

Table 1 demonstrates the breakdown of the numbers of the 3,311 subjects in this study by schools, sex, and school meals. School A with 1,071 students (528 boys and 543 girls) and School B with 920 students (468 boys and 452 girls) were measured and neither were provided school meals. Moreover, School C with 646 students (340 boys and 306 girls) and School D with 674 students (357 boys and 317 girls) were measured in the rural areas and only School C was provided with school meals.

Table 2 represents the descriptive statistics of anthropometric measurements by sex. The reported reference values for the height of Japanese children aged 6 to 10 (13) were 114.8, 120.1, 127.9, 132.4, and 138.9 cm for boys and 114.4, 120.3, 127.0, 133.1, and 138.8 cm for girls. The values for body weight were 20.4, 23.1, 26.7, 29.5, 33.9 kg for boys and 20.0, 22.6, 26.0, 29.1, 32.6 kg for girls. Similarly, BMI was 15.42, 16.01, 16.30, 16.76, and 17.52 kg / m2 for boys and 15.25, 15.58, 16.08, 16.39, and 16.87 kg / m2 for girls. The average height, weight, and BMI values for boys and girls between the ages of 6 and 10 for were clearly lower in Cambodian children in comparison with the Japanese children.

The results of anthropometric and body composition data were summarized in Tables 3 and 4. We conducted two-way ANOVA on the conditions and the results in height showed significant differences in the subgroups of age and schools (regional) ($P<0.001$ and $P<0.001$ for boys and $P<0.001$ and $P<0.001$ for girls). Body weight also depicted significant differences in them ($P<0.001$ and $P<0.001$ for boys and $P<0.001$ and $P<0.001$ for girls). In other words, height and body weight increased significantly with age and it was clear that the students in Schools A and B in urban areas were larger in body size than the rural schools (Schools C and D). However, no differences between Schools C and D were found due to the provision of school meals. BMI which indicates the degree of weight in terms of height showed similar differences of region and provided school meals in height and body weight ($P<0.001$ and $P<0.001$ for boys $P<0.001$ and $P<0.001$ for girls).

Afterwards, we presented the body composition results. The muscle mass showed similar results for height and increased with age and muscle mass was greater in urban schools than in rural schools ($P<0.001$ and $P<0.001$ for boys and $P<0.001$ and $P<0.001$ for girls). Moreover, FFMI, which is a relative measure of body size, also illustrated similar differences in the height in the subgroups of age and schools; however, it should be noted that FFMI was significantly greater in School C with school meals than in School D without school meals for both genders. Additionally, there were no significant differences between urban schools and School C, especially for girls ($P<0.001$ and $P<0.001$ for boys and $P<0.001$ and $P<0.001$ for girls). On the other hand, body fat percentage followed similar age trends as height, body weight, and BMI, but the difference increased significantly with age for School A in urban areas compared to the other schools and this was more obvious for boys ($P<0.001$ and $P<0.001$, $P<0.001$ and $P<0.001$). The results for body fat percentage were similar for FMI, which is relativization between fat mass and height ($P<0.001$ and $P<0.001$, $P<0.001$ and $P<0.001$). Height, BMI, and muscle mass showed clearly higher values with age increase in School A and School B in urban areas than schools in rural areas, indicating a larger body mass at each age. On the contrary, body fat percentage and FMI were clearly higher in urban areas, especially in School A in the capital Phnom Penh where they were about 1.5 to 2 times higher than rural schools.

A body composition chart is illustrated in Figure 1. The contribution of fat-free mass and fat mass to BMI shows that fat mass / height^2 is plotted on the Y-axis against fat-free mass / height^2 on the X-axis by sex and schools. The dotted lines represent constant BMI values for each. Overall, it is seen that FMI contributes more to the increase in BMI for girls than for boys, which is more noticeable in urban areas compared to rural areas. Urban schools had elevated BMI with higher values at 11 years old compared to rural schools and in rural schools, School C with school meals had elevated BMI with higher values compared to School D without school meals. The balance between FFMI and FMI contributions to the increase in BMI was similar in the rural schools. However, School A for boys appeared to have a clearly higher FMI contribution than School B for boys.

4. Discussion

The purpose of this study was to determine the effects of differences between urban and rural residential

Table 3: Mean of each measurement item by sex, age, school meals, and area in boys

	Boys																	
Age	Not provided SM						Provided SM			Not provided SM			ANOVA					
	School A			School B			School C			School D			Age		Schools		Age*Schools	
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	F	P	F	P	F	P
Height, cm													538.6	<.001	139.3	<.001	2.96	<.001
6	72	114.8	5.1	73	114.6	4.3	49	111.0	5.0	54	112.2	6.8	6<7<8<9<10<11		A>B>C,D			
7	78	121.2	5.7	67	119.3	6.1	59	114.7	5.2	51	114.8	5.1						
8	86	126.7	5.6	65	125.3	4.8	59	119.5	5.9	61	118.7	5.6						
9	98	131.8	6.6	75	128.3	6.0	72	125.8	5.8	63	123.4	5.8						
10	106	137.1	6.3	91	132.5	6.8	58	128.7	6.2	66	128.0	6.3						
11	88	142.3	7.8	97	139.1	7.2	43	132.0	6.2	62	133.9	7.3						
Body weight, kg													181.6	<.001	128.9	<.001	4.24	<.001
6	72	20.4	4.1	73	19.8	2.5	49	18.0	2.1	54	18.4	2.8	6<7<8<9<10<11		A>B>C,D			
7	78	24.0	6.4	67	22.1	3.9	59	19.4	2.6	51	19.2	2.2						
8	86	27.0	6.0	65	24.9	3.7	59	21.2	2.8	61	20.6	2.6						
9	98	30.1	7.5	75	26.6	5.4	72	24.8	3.9	63	22.5	2.5						
10	106	34.4	8.7	91	30.2	7.0	58	26.3	5.1	66	24.7	3.6						
11	88	37.7	10.5	97	34.0	8.4	43	27.7	4.0	62	27.9	4.8						
Body mass index, kg/m^2													26.1	<.001	74.5	<.001	1.89	.020
6	72	15.41	2.19	73	15.03	1.30	49	14.64	0.90	54	14.61	1.05	6<8,9,10,11		A>B>C,D			
7	78	16.21	3.23	67	15.45	1.66	59	14.71	1.55	51	14.57	0.99	7<9,10,11					
8	86	16.69	2.67	65	15.78	1.70	59	14.88	1.05	61	14.61	0.95	8,9<10,11					
9	98	17.16	3.11	75	16.09	2.55	72	15.60	1.43	63	14.75	0.96						
10	106	18.05	3.35	91	17.03	2.80	58	15.84	1.97	66	15.03	1.18						
11	88	18.38	3.68	97	17.37	2.99	43	15.84	1.25	62	15.47	1.59						
Muscle mass, kg													452.8	<.001	128.0	<.001	3.49	<.001
6	72	16.72	1.89	73	16.69	1.57	49	15.43	1.58	54	15.76	2.08	6<7<8<9<10<11		A>B>C,D			
7	78	18.92	2.29	67	18.25	2.20	59	16.59	1.65	51	16.57	1.60						
8	86	21.05	2.35	65	20.49	2.03	59	18.27	2.09	61	17.83	1.90						
9	98	23.04	2.90	75	21.72	2.51	72	20.85	2.50	63	19.44	1.91						
10	106	25.39	3.28	91	23.76	3.12	58	22.05	2.87	66	21.22	2.47						
11	88	27.75	3.81	97	26.75	3.93	43	23.59	2.78	62	23.77	3.22						
Body fat percentage, %													5.96	<.001	93.1	<.001	2.21	.005
6	72	13.3	7.1	73	11.4	3.7	49	10.6	2.6	54	10.3	3.4	n.s.		A>B>C, D			
7	78	15.1	10.0	67	13.1	5.9	59	9.5	2.7	51	9.6	2.9						
8	86	16.3	9.2	65	13.0	5.4	59	9.7	2.7	61	9.4	2.7						
9	98	17.8	10.3	75	13.3	8.1	72	11.3	4.0	63	9.2	3.1						
10	106	19.7	11.1	91	15.5	8.4	58	11.3	5.4	66	9.4	3.3						
11	88	19.6	11.9	97	15.3	8.7	43	10.3	3.3	62	9.9	4.6						
Fat-free mass index, kg/m^2													79.7	<.001	31.9	<.001	1.17	.294
6	72	13.21	0.63	73	13.25	0.62	49	13.04	0.48	54	13.00	0.44	6,7<8,9<10<11		A, B>C>D			
7	78	13.44	0.64	67	13.33	0.56	59	13.27	1.19	51	13.12	0.49						
8	86	13.75	0.85	65	13.64	0.66	59	13.35	0.60	61	13.19	0.51						
9	98	13.80	0.77	75	13.74	0.72	72	13.75	0.65	63	13.34	0.46						
10	106	14.16	0.93	91	14.15	0.70	58	13.90	0.84	66	13.54	0.63						
11	88	14.35	0.90	97	14.45	0.86	43	14.14	0.60	62	13.86	0.74						
Fat mass index, kg/m^2													8.25	<.001	79.3	<.001	2.05	.010
6	72	2.20	1.69	73	1.75	0.73	49	1.56	0.47	54	1.53	0.66	6<9-11		A>B>C,D			
7	78	2.76	2.81	67	2.11	1.26	59	1.43	0.50	51	1.42	0.56	7,8<10,11					
8	86	2.94	2.33	65	2.13	1.18	59	1.47	0.51	61	1.39	0.50						
9	98	3.36	2.78	75	2.34	2.00	72	1.82	0.90	63	1.38	0.58						
10	106	3.92	2.91	91	2.87	2.27	58	1.89	1.28	66	1.45	0.63						
11	88	4.03	3.24	97	2.90	2.37	43	1.66	0.68	62	1.59	1.01						

n: number of samples, SD: standard deviation, SM: school meals, n.s.: non significant; Multiple comparisons were statistically significant only if there was a significant difference (P<0.05). Statistical significance of differences (P<0.05) and ranks are indicated by unequal signs.

Table 4: Mean of each measurement item by sex, age, school meals, and area in girls

Girls																		
Age	Not provided SM						Provided SM			Not provided SM			ANOVA					
	School A			School B			School C			School D			Age		Schools		Age*Schools	
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	F	P	F	P	F	P
Height, cm													609.0	<.001	53.1	<.001	1.05	0.401
6	80	114.5	5.7	93	113.1	4.3	42	109.6	4.1	47	110.4	6.1	6<7<8<9<10<11		A>B>C,D			
7	85	119.1	5.6	52	117.8	4.9	44	116.4	4.5	34	117.0	5.9						
8	93	125.2	6.0	79	123.6	5.5	63	120.4	5.6	41	120.1	4.6						
9	100	130.9	7.6	73	128.6	4.9	45	126.0	6.6	57	124.6	6.1						
10	95	136.0	8.3	83	135.8	7.0	66	131.2	6.0	77	131.2	6.3						
11	90	141.9	7.4	72	141.4	8.0	46	135.8	7.9	61	136.5	8.7						
Body weight, kg													215.3	<.001	50.0	<.001	2.94	.001
6	80	19.9	3.7	93	19.1	3.5	42	17.6	1.8	47	17.5	2.2	6<7<8<9<10<11		A>B>C,D			
7	85	21.9	4.4	52	20.4	3.5	44	20.1	2.7	34	19.6	3.2						
8	93	25.0	5.6	79	23.9	5.0	63	21.8	3.3	41	20.8	2.4						
9	100	28.4	7.0	73	25.2	4.6	45	25.2	4.4	57	23.1	3.4						
10	95	33.0	9.7	83	31.8	8.8	66	27.1	4.6	77	26.6	4.7						
11	90	36.9	9.5	72	35.0	9.9	46	30.2	4.9	61	30.0	6.0						
Body mass index, kg/m^2													33.3	<.001	29.8	<.001	1.64	.058
6	80	15.07	1.92	93	14.87	2.29	42	14.65	1.32	47	14.37	1.07	6,7<9,10,11		A>B>C,D			
7	85	15.39	2.21	52	14.70	1.93	44	14.80	1.26	34	14.25	1.43	8,9<10,11					
8	93	15.84	2.61	79	15.56	2.45	63	14.95	1.47	41	14.36	1.15						
9	100	16.50	2.96	73	15.20	2.17	45	15.75	1.69	57	14.77	1.23						
10	95	17.59	3.81	83	17.04	3.46	66	15.66	1.74	77	15.34	1.73						
11	90	18.14	3.54	72	17.26	3.49	46	16.39	2.31	61	15.93	1.70						
Muscle mass, kg													388.2	<.001	42.5	<.001	1.54	.083
6	80	15.85	2.00	93	15.37	1.72	42	14.57	1.22	47	14.49	1.66	6<7<8<9<10<11		A>B>C,D			
7	85	17.32	2.18	52	16.46	1.97	44	16.46	1.65	34	16.25	2.19						
8	93	19.57	3.06	79	18.75	2.36	63	17.69	2.10	41	17.19	1.63						
9	99	21.47	3.41	73	20.01	2.20	45	19.88	2.59	57	18.81	2.42						
10	95	23.89	4.27	83	23.58	3.96	66	21.69	2.56	77	21.39	2.65						
11	90	26.36	4.20	72	25.90	4.67	46	23.67	3.02	61	23.56	3.80						
Body fat percentage, %													21.5	<.001	42.6	<.001	1.49	.101
6	80	15.7	5.3	93	14.7	6.4	42	13.5	3.6	47	13.2	3.0	6<9,10,11		A>B>C,D			
7	85	16.4	5.9	52	14.4	5.5	44	14.1	3.2	34	12.9	3.8	7,8<10,11					
8	93	17.5	6.4	79	16.3	6.6	63	14.2	4.1	41	13.2	2.8						
9	100	19.0	7.6	73	15.6	5.9	45	15.6	4.1	57	14.3	3.4						
10	95	21.2	9.3	83	19.7	9.2	66	15.2	4.4	77	15.1	4.8						
11	90	22.5	8.7	72	19.5	8.5	46	16.8	4.3	61	16.6	4.1						
Fat-free mass index, kg/m^2													43.4	<.001	13.2	<.001	1.05	.396
6	80	12.61	0.78	93	12.55	0.95	42	12.63	0.68	47	12.46	0.70	6<7<8<9<10<11		A,C>B>D			
7	85	12.74	0.90	52	12.46	0.82	44	12.68	0.69	34	12.37	0.76						
8	93	12.91	0.94	79	12.86	0.91	63	12.77	0.76	41	12.45	0.68						
9	100	13.09	1.00	73	12.71	0.85	45	13.24	1.07	57	12.64	0.63						
10	95	13.52	1.18	83	13.38	1.08	66	13.21	0.76	77	12.95	0.73						
11	90	13.78	1.26	72	13.60	1.30	46	13.55	1.40	61	13.24	0.89						
Fat mass index, kg/m^2													21.8	<.001	37.2	<.001	1.83	.026
6	80	2.46	1.25	93	2.32	1.48	42	2.02	0.78	47	1.93	0.56	6-8<9<10,11		A>B>C,D			
7	85	2.65	1.42	52	2.22	1.26	44	2.12	0.65	34	1.88	0.77						
8	93	2.94	1.77	79	2.69	1.63	63	2.17	0.88	41	1.93	0.57						
9	100	3.32	2.02	73	2.49	1.42	45	2.51	0.92	57	2.14	0.69						
10	95	4.07	2.88	83	3.65	2.67	66	2.45	1.12	77	2.39	1.16						
11	90	4.36	2.59	72	3.65	2.39	46	2.82	1.20	61	2.70	0.96						

n: number of samples, SD: standard deviation, SM: school meals; Multiple comparisons were statistically significant only if there was a significant difference (P<0.05). Statistical significance of differences (P<0.05) and ranks are indicated by unequal signs.

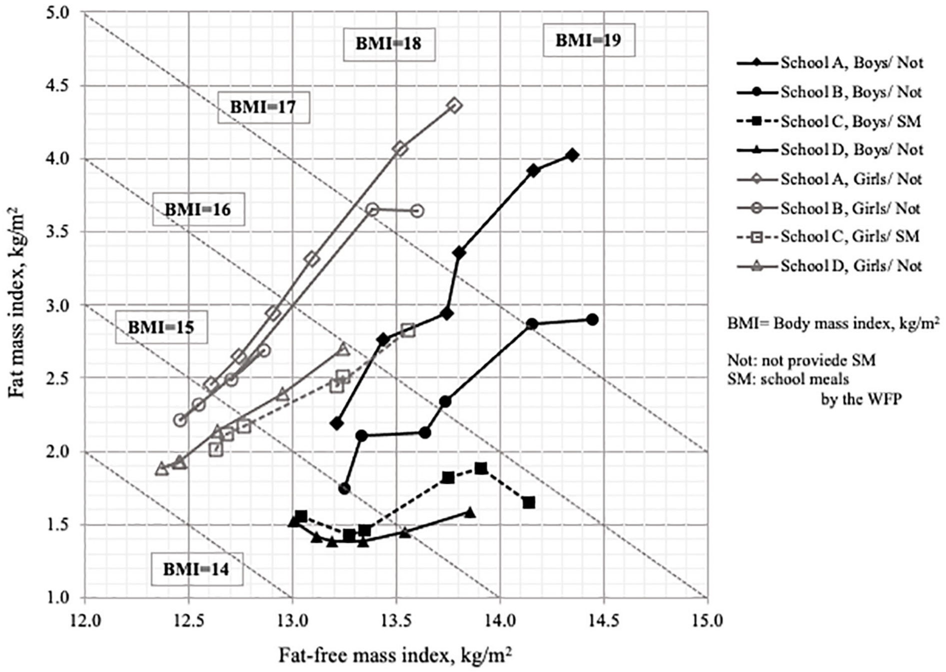

Figure 1: The figure shows body composition chart using average values for 6 to 11-year-old children by sex and schools.

areas in Cambodia and the school meals provided or not on the growth and body composition of primary school children. Asia is expected to have more than 100 million people with type 2 diabetes by 2025 (14). Moreover, the rapid increase in diabetes in Asia differs from other countries in the way that it is increasing even among younger adults and those with lower BMI (15). Therefore, it is important to clarify the growth and body composition of developing Asian countries to provide basic data for prophylactic. Compared to Westerners, Japanese children had lower FFM (16) and Singaporean children had higher subcutaneous fat mass and higher %fat despite shorter, lighter, and lower BMI (17). Moreover, the WHO expert conclusion demonstrated that Asians have higher levels of obesity and a different distribution of fat accumulation, even with the same BMI values (18). Even if they have the same BMI as Westerners, Asians show higher body fat percentage, obvious abdominal obesity, and higher liver fat accumulation (19). Similarly, the relationship between body fat percentage and BMI has racial characteristics (20) and Asians are more susceptible to diabetes than other regions (21). It has been reported that lifestyle-related diseases, such as obesity, are becoming more apparent in developing countries. This is thought to be due to urbanization, changes in eating habits, and decreased physical activity caused by rapid economic development (22, 23). The results of this study implied that body size was clearly larger in urban areas than in rural areas. In addition, body fat percentage and FMI also showed higher age trends, especially their age trends for children in School A in the capital city of Phnom Penh were 1.5 to 2 times higher than for children in rural areas. The situation in Phnom Penh, the capital city of Cambodia, shows a high population density along with the density of population per km^2, with the population increasing about 1.6 times in the period from 2008 to 2019. When comparing urban and rural areas, the population density in urban areas increased 2.6 times from 372 in 2008 to 874 persons / km^2 in 2019 while rural areas showed a decrease from 63 to 55 persons / km^2, indicating a significant population inflow to urban areas. The concentration of economic activity has led to overcrowding in Phnom Penh's population and the rapid increase in the use of motorcycles and cars has led to major changes in lifestyle habits, such as eating and exercise, which are likely to have an impact on child development and obesity rates (24). Moreover, a comparison between urban and rural areas implies that the urban population density increased 2.6 times from 372 persons/km^2 in 2008 to 874 persons/km^2 in 2019 whereas rural areas showed a decrease from 63 persons/km^2 to 55 persons/km^2, indicating a significant population shift to urban areas (25).

Similar to our study, Nabetani and Chiba (25) reported that the height and body weight of Cambodian children living in urban areas were also higher than those living in other regions. Furthermore, the body size was generally smaller and the reversal between boys and girls seemed to occur one to two years later than in Japan and the growth rate of Cambodian children is considered to be slower than that of Japanese children. The data of this study were compared with the Japanese data (13). For both sexes, the height, body weight, and BMI of 6-year-old children at School A in Phnom Penh were almost the same as those of Japanese children; however, rural children were clearly smaller than Japanese children (Japanese 6-year-old boys: height 114.8 cm, body weight 20.4 kg, BMI 15.4 kg/m^2; girls: height 114.4 cm, body weight 20.0 kg, BMI 15.2 kg/m^2). Moreover, comparing the 10-year-olds, the height of 10-year-old children at School A was slightly smaller than that of Japanese children; however, their body weight and BMI were greater than those in Japan. On the other hand, the gap between rural children and Japanese children at age 10 was much larger than at age 6. (Japanese 10-year-old boys: height 138.9 cm, body weight 33.9 kg, BMI 17.5 kg/m^2; girls: height 138.8 cm, body weight 32.6 kg, BMI 16.9 kg/m^2).

Additionally, it is notable that the area of School C with school meals was considered poorer than those of other rural primary schools during our developmental study. We confirmed this along with our Cambodian co-researcher and local coordinator. Nonetheless, there were no significant differences in height, body weight, or muscle mass among the rural primary schools and FFMI showed age trends comparable to those of School B. The effects of school meals provision on growth and anthropometric indicators in developing countries is still inconclusive as a study showed a positive effect of school meals while other studies state no effects (26). However, the result in the present study indicated that the provision of school meals may have a positive effect on the development of body structures, such as the build and muscle mass.

Herein, we created body composition charts to show the relationship between FFMI and FMI with children's growth. The BMI is a simple measurement used worldwide as a valid method of indicating nutritional status and degree of obesity. On the other hand, it is not clear whether the BMI value which constitutes body weight increases or decreases due to the influence of fat mass or fat-free mass. Therefore, Hattori and colleagues (27) calculated the fat-free mass index (FFMI, kg/m^2) and fat mass index (FMI, kg/m^2), adjusted for the effects of body size on FFM and FM, and created a two-dimensional planar graph and a body composition chart. One of the advantages of using FFMI and FMI for assessing body composition is that they are characteristically independent of body size as there are no significant correlations between height and these indicators. This is useful in intervention programs because body composition can be categorized into high-fat/high-muscle, low-fat/high-muscle, high-fat/low-muscle, and low-fat/low-muscle types and its dynamics can be visually captured with the graph. From this chart, the age development in urban primary schools showed higher BMI values than in rural areas and this appeared to be more due to increased FMI for boys in School A than in School B. In a comparison of rural primary schools, the balance between FFMI and FMI was similar with age-related increases in BMI; however, BMI at age 11 in School C increased with age higher than in the other primary schools, providing a glimpse of the effects of school meals provision.

4.1. Limitations

The present study revealed significant regional differences in the body size and body composition of Cambodian children and there was a slightly positive effect of school meals provision on children's growth. However, the current research still faced three major challenges: first, the study did not cover all the children in Cambodia and the number of subjects was insufficient, resulting in an uneven graph; second, the study did not examine the daily habits of Cambodian children, especially their diet, which limited its ability to show the effects of school meals provision; and third, we employed a body composition analyzer for Japanese children because there were no devices available for Cambodians. Therefore, although we think that our results are valid enough to compare the regional differences of children's growth, the accuracy of the values is expected to be low for use as reference values. However, knowing the limitations, it is important to identify standardized growth patterns and reference values or changes in body composition for understanding the relationships between development, health, and disease and for providing health education (28). Therefore, we are planning to continue to undertake further research for growth and development in Cambodian children.

5. Conclusion

The purpose of this study was to assess whether the area of residence and the availability of school meals provision affect the body size and composition of school children. The results showed a clearly larger body size in urban schools compared to rural schools and the schools with school meals provision in rural areas also demonstrated good effects. The results also showed that the body fat percentage and fat mass index were nearly twice as high in urban schools than in rural schools. In other words, the study shed light on the need for health education in terms of overnutrition and undernutrition among Cambodian children.

Ethical Approval

This study was conducted in compliance with the Declaration of Helsinki, the Ethical Guidelines for Clinical Research, and the Act on the Protection of Personal Information. In addition, this study was conducted according to the regulations imposed by the "Cambodia Health Education Project" by Aichi University of Education and Cambodia's Ministry of Education, Youth, and Sport. Also, written informed consent was obtained from the participants.

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