MULTIVARIATE ANALYSES OF CROSS-SECTIONAL GROWTH DATA

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Introduction

The study of human biological variation and nutritional intake can profit from the application of multivariate methods such as principal components analysis, canonical correlation analysis and multiple regression analysis and so forth.

According to RELETHFORD *et al.*[1] cross-sectional data consisting of 33 anthropometric measures of the body and head, on a sample 256 Irish boys 8 to 12 years old, were analyzed by multivariate method. Principal components extraction followed by varimax rotation produced five orthogonal components accounting for nearly 79% of total variation. The first component had a high positive correlation with age and showed a constant increase across the age range studied.

MUELLER *et al.* reported[2] in regard to the association of lung function and 14 body measurements of child and adult permanent residents of an altitudinal gradient in northern Chile. It was explored by principal components and canonical correlation, multivariate methods with which the importance of both size and body proportion in physiological efficiency was assessed. Physical growth was different at high and low altitudes, higher altitude childern having greater chest development relative to height. The first 2 canonical correlations of a possible 4, were significant. Both indicate chest measurements as the main physical correlates of lung function irrespective of altitude, sex or age group, but these correlations depended on ethnicity (Spanish-Amerindian ancestry) as they increase substantially when that factor was held constant.

SUZUKI *et al.*[3] studied to know the size and cause of inter-individual variation of nutritional intake, 30-day dietary records and somatic characteristics of 42 female students (age 18–19 years) living in a college dormitory were analyzed. (1) The inter-individual variation was greatest for vitamins

A and C, and smallest for protein in nutritional intake, and the greatest and the next greatest were for body weight and lean body mass and the smallest was for proportion of fat to weight in somatic characteristics. (2) No items of somatic characteristics could explain the inter-individual variation of nutritional intake. (3) The amount of intake of nutrient per kg of body weight was inversely correlated with the somatic characteristic, but hemoglobin content, which suggested the size of body, had a significance in regulating the dietary intake in this group as a reducing factor.

TOYOKAWA *et al.*[4] analyzed in relation to secular change of food consumption pattern in Japan 1949–1978. The data available were part of the national nutrition survey conducted by the Ministry of Welfare every year since 1946. The results of principal component analysis revealed that the first and second components represent essential vs. non-essential and traditional vs. modern as X and Y axes respectively, and national data indicated a tendency from essential and traditional to non-essential and modern according to the interpretation of the components.

GUTHRIE *et al.*[5] considered that in order to reduce the number of measurements used to assess nutritional status without an appreciable loss of diagnostic value, it is necessary to know the statistical relationships among the measures themselves. They reported the results of a factor analysis of 32 variables consisted of anthropometric, nutrient intake based on a 2-day food intake record, and biochemical measures on 419 preschool children between 12 and 72 months of age and represented a wide range of socioeconomic levels and geographic regions in USA.

The 1976 survey for physical measurements and food consumption of Hokkaido orphanage children was conducted by SANTO and her assistants who weighed and measured all of them and did two days survey of their food intake by using weighing method individually for all subjects. The nutrient intake was calculated from the food consumption data by using food composition tables.

The physique of these children is obviously influenced by their routine diet.

In spite of the 2 days' survey, their individual food consumption weighed in the dining room revealed that their daily dietary intake did not differ much from their routine one. The reasons were (1) that the efficient cooperation of the supervisors and staff members has been steady throughout the surveys during the 5- or 6-year intervals since 1960, although different orphanage children have been dealt with ; (2) the menus on the days of survey were just ordinary ones, for in most institutions, their menus were planned monthly, and the days set for the survey were on ordinary weekdays ; (3) the amount of contents for each child was weighed and served according to his or her regular appetite within the orphanage, on the other hand, the data on regular school lunches in public schools were collected by Santo by the interview method to avoid social inferiority complex in orphans ; (4) previous reports on this survey of the association between anthropometric data and nutrient intake have not been completed yet.

The purpose of this paper is as follows : 1. To identify the patterns of variation in physique and dietary intake as revealed by principal components analysis for Hokkaido orphanage children. 2. To interpret these patterns in terms of their relationship by multiple regression analysis.

Materials and Methods

1. *Samples.* The subjects who participated in the nutrition survey for Hokkaido orphanage children in 1976, consisting of 1518 healthy children, 1-18 years of age, lived in 25 social welfare institutions scattered throughout Hokkaido, the northern-most and second largest of the four major islands of Japan (Fig. 1) where yearly average temperature is about 7 degrees Centigrade[6]. The subjects were grouped into sex and age as shown in Table 1. Chronological ages were those obtained by the record kept at the institutions.

2. *Methods.* The head and body measurements for this study include height, weight, chest circumference, sitting height, head circumference, upper arm cricumference, triceps skinfold, subscapular skinfold, upper arm muscle area, upper arm fat area and upper arm muscle ratio[7,8,9]. The daily nutrient intake data involve energy, protein, fat, calcium, iron, vitamin A, vitamin D, thiamine, riboflavin, niacin equivalent and ascorbic acid[7,8,9].

1) Principal component analysis was performed to determine the minimum number of independent dimensions needed to account for most of the variance in the original set of variables.

2) Multiple regression analysis was to predict the linear relationship between anthropometric data and nutrient intake by using component score of anthropometric data as a dependent variable, and the component score of nutrient intake as an independent variable to predict the former based on the information of the latter.

The programs of factor analysis and multiple regression analysis of SPSS[10,11] were run on FACOM 230-60/75 of the Computer Center of Hokkaido University. The interpretation of the results has been done by the citation of the literatures, OKUNO *et al.*[12], KAWAGUCHI[13], COOLEY *et al.*[14],

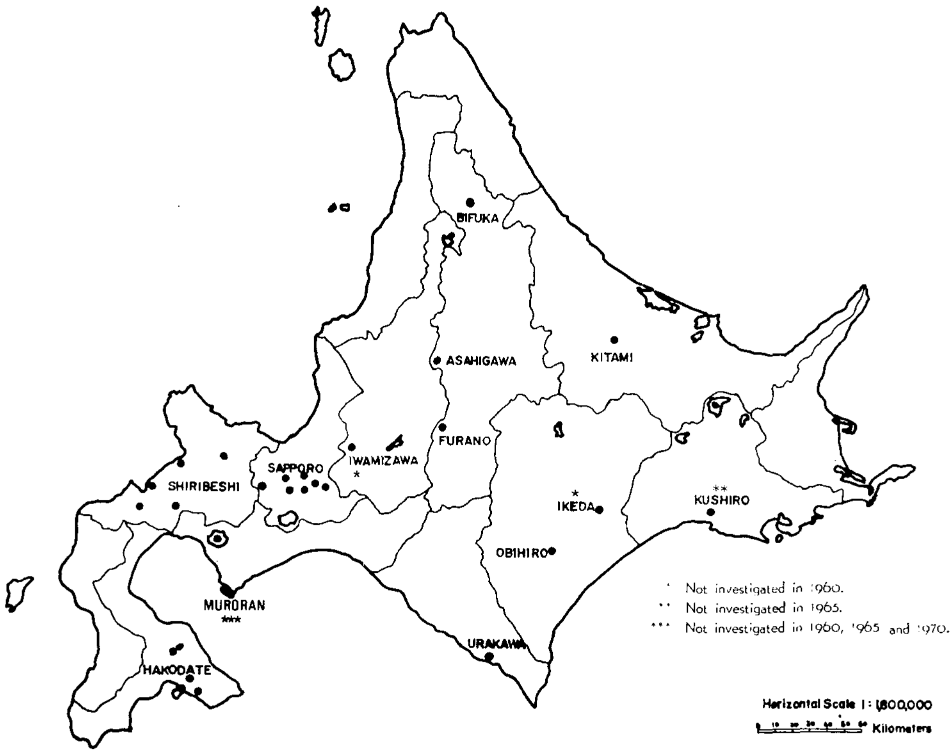

Fig. 1. Location of 25 orphanages in Hokkaido.

TABLE 1. Sex and age composition of Hokkaido orphanage children in 1976

Group	Sex	Range in years	Sample size
M_1	Male	1.0– 5.9	140
M_2	Male	6.0–11.9	461
M_3	Male	12.0–18.9	344
F_1	Female	1.0– 5.9	91
F_2	Female	6.0–11.9	259
F_3	Female	12.0–18.9	223
E	Male & Female	1.0–18.9	1,518

KOBAYASHI[15] and WESOLOWSKY[16].

Results and Discussion

1. *Descriptive statistics.*

The descriptive statistics of anthropometric measures and dietary intake of Hokkaido orphanage children in 1976 have been shown in Tables 2 and 3 respectively. After this, investigations would mainly involve the E group, the entire children, and in case of any significances in sex and age, such facts would be added.

Because of differences in the unit for mean and standard deviation, the investigation revealed coefficient of variation which was shown by relative size of deviation.

1) Physical characters. (Table 2)

In group E, the entire sample, the minimum value of the coefficient of variation was 4.8% in head circumference; the next was trunk including sitting height and chest circumference; then, followed characters of limb growth including height, arm cricumference, arm muscle ratio, arm muscle area and weight. The maximum group involved skinfold thicknesses (triceps and subscapular) and arm fat area. Therefore, there was the tendency of coefficient of variation becoming greater in the following order: head size, trunk, limbs and skinfold thickness in group E. The ones of triceps skinfold and arm fat area of the groups M_1 and F_1 were found considerably small in comparison with the other 4 groups.

2) Nutrient intake. (Table 3)

In group E, the 7 nutrients including energy, protein, fat, calcium, iron, riboflavin and niacin equivalent showed a comparatively close range. However, vitamins A, D, thiamine and ascorbic acid showed wide differences. Individual variation among the 6 groups, M_1–F_3, indicated similar tendencies in group E.

2. *Principal component analysis.*

According to the anthropometric and dietary data, in each of the seven analyses, the procedure was the same: respective 11 by 11 matrix of correlation coefficients were computed. Principal component analysis is applied to those data to determine how many independent sources of variance are really being assessed by the 11 variables.

Table 4 indicated the eigenvalue above 0.85 and the proportion of principal component analysis. In order to obtain the information of approximately 80% of the total variance, the eigenvalue above 0.85 was used.

TABLE 2. Anthropometric measurements in 7 groups of Hokkaido orphanage children in 1976

Variable	Mean						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Height (cm)	98.6	126.7	154.1	98.7	128.4	150.6	132.5
2. Weight (kg)	15.5	26.7	44.7	15.5	28.0	45.9	32.1
3. Chest circumference (cm)	54.1	63.6	76.1	53.2	63.5	78.6	67.1
4. Sitting height (cm)	57.1	69.6	82.6	57.2	70.3	82.2	72.6
5. Head circumference (cm)	50.0	52.3	54.2	49.2	51.8	53.8	52.5
6. Upper arm circumference (cm)	16.6	19.3	23.4	16.6	19.6	24.0	20.6
7. Triceps skinfold (mm)	11.0	10.1	10.5	11.8	12.7	19.4	12.2
8. Subscapular skinfold (mm)	6.8	7.0	8.7	8.0	9.5	18.4	9.5
9. Arm muscle area (mm^2)	13.9	21.1	32.6	13.3	19.8	25.6	23.0
10. Arm fat area (mm^2)	8.2	9.0	11.6	8.7	11.2	20.7	11.6
11. % of total arm area which is muscle (%)	62.9	70.4	74.3	60.4	64.6	56.7	67.0

Variable	Standard Deviation						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Height (cm)	8.8	9.9	10.1	10.2	11.3	6.2	20.9
2. Weight (kg)	2.7	5.5	9.2	2.7	6.6	7.6	12.8
3. Chest circumference (cm)	2.7	4.6	6.5	2.8	5.6	6.6	10.0
4. Sitting height (cm)	4.0	4.4	5.6	4.7	5.3	3.6	9.9
5. Head circumference (cm)	1.7	2.3	1.8	1.8	1.8	2.0	2.5
6. Uupper arm circumference (cm)	1.2	2.3	2.5	1.3	2.0	2.5	3.4
7. Triceps skinfold (mm)	2.5	3.4	5.0	2.4	5.5	6.6	5.6
8. Subscapular skinofold (mm)	2.2	3.1	4.0	2.7	3.6	8.5	5.9
9. Arm muscle area (mm^2)	2.6	8.9	7.5	2.8	3.7	4.3	9.0
10. Arm fat area (mm^2)	2.0	3.5	6.1	1.9	4.5	8.2	6.4
11. % of total arm area which is muscle (%)	6.9	7.4	9.6	7.1	8.5	9.8	10.4

Variable	Coefficient of Variation						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Height (%)	8.9	7.8	6.6	10.3	8.8	4.1	15.7
2. Weight (%)	17.4	20.6	20.6	17.4	23.6	16.6	39.8
3. Chest circumference (cm)	5.0	7.2	8.5	5.3	8.8	8.4	14.5
4. Sitting height (%)	7.0	6.3	6.8	8.2	7.5	4.4	13.7
5. Head circumference (cm)	3.4	4.4	3.3	3.7	3.5	3.7	4.8
6. Upper arm circumference (cm)	7.2	11.9	10.7	7.8	10.2	10.4	16.5
7. Triceps skinfold (%)	22.7	33.7	47.6	20.3	43.3	34.0	45.9
8. Subscapular skinfold (%)	32.4	44.3	46.0	33.8	37.9	46.2	62.1
9. Arm muscle area (%)	18.7	42.2	23.0	21.1	18.7	16.8	39.1
10. Arm fat area (%)	24.4	38.9	52.6	21.8	40.2	39.6	55.7
11. % of total arm area which is muscle (%)	11.0	10.5	12.9	11.8	13.2	17.3	15.5

TABLE 3. Daily dietary intake in 7 groups of Hokkaido orphanage children in 1976

Variable	Mean						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Energy (Cal)	1,372	2,117	2,826	1,311	1,910	2,215	2,140
2. Protein (g)	45.6	72.8	93.2	43.0	66.7	78.1	72.9
3. Fat (g)	41.0	62.1	78.4	39.3	60.9	68.6	63.2
4. Calcium (mg)	436	677	748	409	655	703	655
5. Iron (mg)	7.7	12.1	15.4	7.4	11.5	13.3	12.2
6. Vitamin A (IU)	1,077	1,673	1,817	1,026	1,558	1,751	1,603
7. Vitamin D (IU)	39	114	119	45	101	126	104
8. Thiamine (mg)	1.00	1.65	2.20	0.90	1.57	1.79	1.68
9. Riboflavin (mg)	0.96	1.43	1.70	0.91	1.41	1.51	1.42
10. Niacin equivalent (mg)	17.6	28.2	36.5	16.6	25.2	30.5	28.2
11. A scorbic acid (mg)	52	80	90	48	71	86	77
Variable	Standard Deviation						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Energy (Cal)	245	354	512	239	331	359	597
2. Protein (g)	9.3	12.4	16.5	8.6	11.3	13.4	19.9
3. Fat (g)	9.8	15.0	22.9	9.2	14.0	17.2	20.4
4. Calcium (mg)	123	162	172	114	155	148	186
5. Iron (mg)	1.7	2.2	2.7	1.7	2.2	2.7	3.3
6. Vitamin A (IU)	350	567	662	295	469	580	600
7. Vitamin D (IU)	47	120	144	63	110	145	124
8. Thiamine (mg)	0.45	0.74	1.20	0.38	0.64	0.66	0.89
9. Riboflavin (mg)	0.25	0.31	0.39	0.24	0.38	0.35	0.41
10. Niacin equivalent (mg)	3.8	5.4	7.2	3.6	5.1	6.2	8.3
11. Ascorbic acid (mg)	19	26	30	18	24	29	29
Variable	Coefficient of Variation						
	M_1	M_2	M_3	F_1	F_2	F_3	E
1. Energy (%)	17.9	16.7	18.1	18.2	17.3	16.2	27.9
2. Protein (%)	20.4	17.0	17.7	20.0	16.9	17.2	27.3
3. Fat (%)	23.9	24.2	29.2	23.4	23.0	25.1	32.3
4. Calcium (%)	28.2	23.9	23.0	27.9	23.7	21.1	28.4
5. Iron (%)	22.1	18.2	17.5	23.0	19.1	20.3	27.0
6. Vitamin A (%)	32.5	33.9	36.4	28.8	30.1	33.1	37.4
7. Vitamin D (%)	120.5	105.3	121.0	140.0	108.9	115.1	119.2
8. Thiamine (%)	45.0	44.8	54.5	42.2	40.8	36.9	53.0
9. Riboflavin (%)	26.0	21.7	22.9	26.4	27.6	23.2	28.9
10. Niacin equivalent (%)	21.6	19.1	19.7	21.7	20.2	20.3	29.4
11. Ascorbic adic (%)	36.5	32.5	33.3	37.5	33.8	33.7	3.77

TABLE 4. Eigenvalue and the proportion of principal component analysis on nutritional status for Hokkaido orphanage children in 1976

	Component	M_1		M_2		M_3		F_1		F_2		F_3		E	
		EV	P	EV	P	EV	P	EV	P	EV	P	EV	P	EV	P
Anthropmetric	P'_1	5.22	47.4	5.48	49.8	6.06	55.1	5.51	50.1	6.61	60.1	6.49	59.0	6.74	61.2
	P'_2	3.44	31.3	5.66	24.2	3.17	28.8	3.18	28.9	2.64	24.0	1.72	15.7	2.94	26.7
	P'_3			1.27	11.6			0.86	7.8			1.21	11.0		
	P'_4			0.89	8.1										
	$\sum_{i=1}^{4} P'_i$		78.8		93.6		83.9		86.8		84.1		85.7		88.0
Nutritional	N'_1	5.37	48.8	5.51	50.0	5.56	50.5	5.48	49.8	5.45	49.6	5.45	49.5	6.67	60.7
	N'_2	1.41	12.8	1.52	13.8	1.31	12.0	1.36	12.3	1.36	12.4	1.35	12.3	1.15	10.4
	N'_3	1.07	9.8	1.12	10.2	1.29	11.7	1.91	10.8	1.21	11.0	1.25	11.4	1.02	9.3
	N'_4	0.98	8.9	0.92	8.3	0.93	8.4	0.89	8.1	1.51	10.5	0.89	8.1		
	$\sum_{i=1}^{4} N'_i$		80.3		82.4		82.6		81.1		83.4		81.2		80.4

1, 2, 3, 4 with N′ or P′ on the component column represent the first, second, third, fourth components respectively. EV: Eigenvalue $\geqq 0.85$. P: Prorortion. $\sum_{i=1}^{4} P'_i$: Accumulated proportion: $\sum_{i=1}^{4} N'_i$

In regard to the physical characters, 78-88% as the accumulated proportions were accounted for two principal components in the four groups of M_1. M_3, F_2 and E; 85-87% for three principal components in groups F_1 and F_3; and 94% for four principal components in group M_2.

In relation to nutrient intake, the proportion was nearly 80% for three principal components in group E, and 80-83% for four principal components in the six groups, M_1-F_3.

In order to interpret the importance of how 11 variables contribute to each component, varimax rotation was performed on all the components, and the resultant loadings are shown in Figures 2 and 3.

1) Physical characters (Fig. 2)

According to Fig. 2, rotated factor loadings (varimax solution) of the first, second, third and fourth components were plotted on the plane by rectangular co-ordinate axes of (P_1 and P_2), (P_2 and P_3), (P_3 and P_4). Only loadings whose values were greater than an arbitrary cutoff of 0.5 were plotted and grouped by broken line.

Inspection of factor loadings revealed the first component to contain only positive loadings, whereas, the second component contained mixed signs in

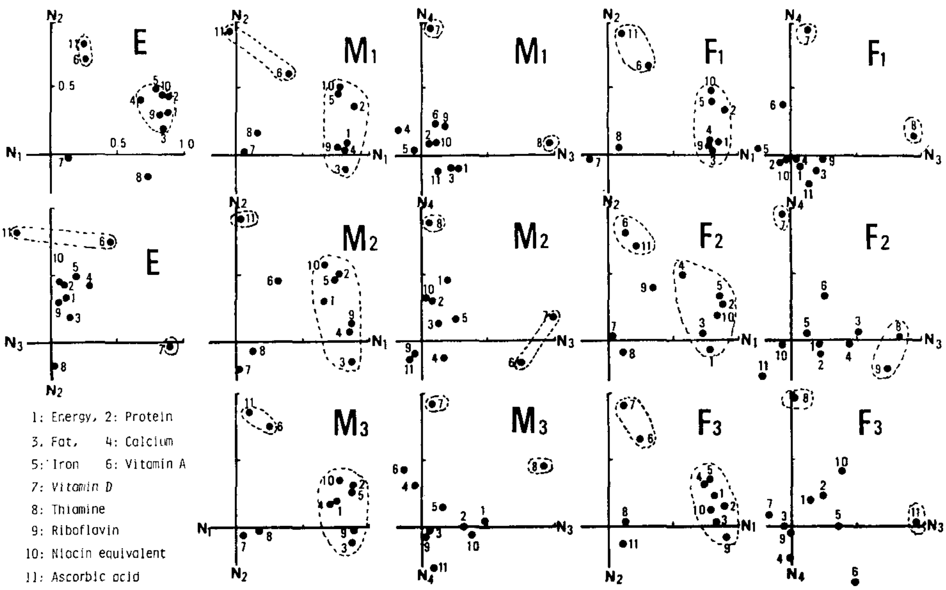

Fig. 2. Rotated components loadings (varimax solution) on anthropometric measurements of Hokkaido orphanage children in 1976. Only loadings whose values were greater than an arbitrary cutoff of 0.5 were grouped by broken line. 1: Height, 2: Weight, 3: Chest circumference, 4: Sitting height, 5: Head circumfence, 6: Upper arm circumference, 7: Triceps skinfold, 8: Subscapular skinfold, 9: Upper arm muscle area, 10: Upper arm fat area, 11: Upper arm muscle ratio.

group E. This was often taken to reveal the first component as a size factor (body size) and subsequent bipolar component to represent a shape factor (depot fat). The first component had high loadings for those variables associated with height, weight, chest circumference, sitting height, head circumference, upper arm circumference, and upper arm muscle area. The second component showed four high loading variables associated with triceps skinfold, subscapular skinfold, upper arm fat area and upper arm muscle ratio.

The results of the same analysis for the six groups, M_1-F_3, showed remarkable differences by sex and age. In the four groups, M_1-M_3 and F_2, as the size factor, the first component included height, weight, chest circumference and sitting height in common for high loading variables; as the shape factor, second component showed the highest loading for triceps skinfold or upper arm muscle ratio. In the case of the two groups F_1 and F_3, on the other hand, the first component showed high loadings for those variables associated with triceps skinfold, subscapular skinfold, upper arm fat area and upper arm muscle ratio in common, and weight, chest and upper arm circumferences in group F_3; height and sitting height showed high loadings as the second component; therefore, it appeared that the first and second components represented the shape and size factors respectively. Those interpretations were contrary to the other four groups, M_1–M_3, F_2 and E. In the three groups, M_2, F_1 and F_3, the third component, representing high loading of upper arm circumference and upper arm muscle area, was interpreted as a muscle size. In group M_2, the fourth component was interpreted as a head size, because of the highest loading of head circumference.

2) Nutrient intake (Fig. 3)

According to Fig. 2, in group E, the first component (N_1) was interpreted as a size factor (nutrient intake size) for containing only positive loadings. The high loading variables were 8 nutrients including energy, protein, fat, calcium, iron, thiamine, riboflavin and niacin equivalent. As high loading nutrient, vitamin A and ascorbic acid appeared in the second

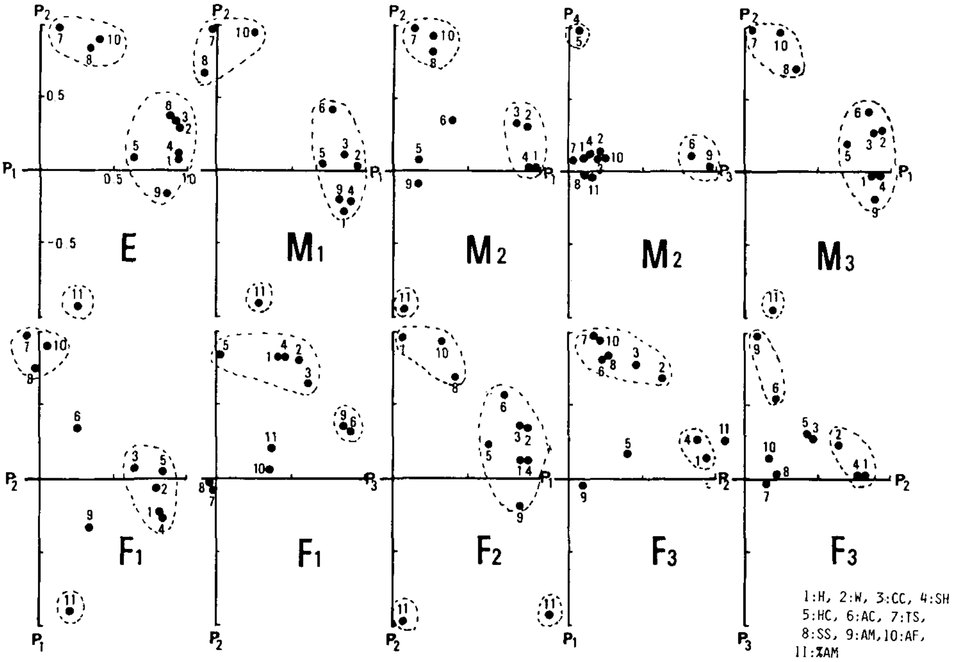

Fig. 3. Rotated components loadings (Varimax solution) on nutrient intake of Hokkaido orphanage children in 1976. Only loadings whose values were greater than an arbitrary cutoff of 0.5 were grouped by broken line.

component (N_2); vitamin D in the third component (N_3). However, it was difficult to interpret the second and third components.

In the six groups, M_1–F_3, almost same tendencies were shown as group E did, although four components were extracted in each of them, and some high loading nutrients, such as thiamine in every group and riboflavin in group F_2, transferred from the first component to the other ones.

Table 5 revealed summarized interpretation of components for the anthropometric and dietary data in the seven groups, M_1–F_3 and E. In relation to the anthropometric data, the first and second components were the body size and the depot fat respectively in the five groups, M_1–M_3, F_2 and E. On the contrary, the opposite phenomena were found in the remaining two groups, F_1 and F_3. The third component was obtained as a muscle size in the three groups, M_2, F_1 and F_3, and the fourth component was interpreted as a head size in group M_2. Regarding the nutrient intake the first component was interpreted as a nutrient intake size including 8 nutrients in group E, and 7 or less nutrients in the six groups, M_1–F_3; Vitamins A, D, thiamine, riboflavin and ascorbic acid as the second, third and fourth components which showed different combinations.

It was considered that just an ordinary meal had been served to the subject children for two days during the investigation period in most of the institutions. As far as the children's dietary intake is concerned, it is obvious

TABLE 5. Interpretation of orthogonal components produced by varimax rotation of principal components extraction on nutritional survey for Hokkaido orphanrge children in 1976

Component		M_1	M_2	M_3	F_1	F_2	F_3	E
Anthropometric	P_1	Body size	Body size	Body size	Depot fat	Body size	Depot fat	Body size
	P_2	Depot fat	Depot fat	Depot fat	Body size	Depot fat	Body size	Depot fat
	P_3		Muscle size		Muscle size		Muscle size	
	P_4		Head size					
Nutritional	N_1	N. I. size	N. I. size	N. I. size	N. I. size	N. I. size	N. I. size	N. I. size
	N_2	V–A, C	V–C	V–A, C	V–A, C	V–A, C	V–A, D	V–A, C
	N_3	V–B_1	V–A, D	V–B_1	V–B_1	V–B_1, B_2	V–C	V–D
	N_4	V–D	V–B_1	V–D	V–D	V–D	V–B_1	

M: Male, F: Female, E: Entire sample, N. I. size: Nutrient intake size, V–A: Vitamin A, V–B_1: Thiamin A, V–B_2: Riboflavin, V–C: Ascorbic acid, V–D: Vitamin D.

that the nutrients showing high loadings in the first component could be provided for the subjects naturally if energy and protein intake would be considered. However, in the remaining components to their high loading nutrients, such as vitamin A, thiamine, riboflavin, ascorbic acid and vitamin D, special attention ought to be paid on menu planning and food preparation.

3. *Multiple regression analysis.*

In order to explore how the nutrient intake contributed to their physique, multiple regression analysis was performed by using the score of the four components, P_A (body size), P_B (depot fat), P_C (muscle size) and P_D (head size), as dependent variables, and the score of four components, N_1 (nutrient intake size), N_2, N_3 and N_4, as independent variables. The results were shown in Table 6.

TABLE 6. Multiple regression analysis of principal component score on nutritional status for Hokkaido orphanage children in 1976

Group	Dependent variable	Multiple regression formula estimated	Proportion (%)
M_1		$0.370 N_1+0.402 N_2+0.362 N_3+0.045 N_4$	43.1**
M_2		$0.408 N_1+0.310 N_2+0.164 N_3+0.372 N_4$	42.8**
M_3		$0.263 N_1+0.190 N_2+0.246 N_3-0.063 N_4$	17.0**
F_1	P_A (Body size)	$0.350 N_1+0.148 N_2+0.236 N_3+0.149 N_4$	22.2**
F_2		$0.438 N_1+0.048 N_2+0.191 N_3-0.044 N_4$	23.3**
F_3		$0.064 N_1+0.080 N_2+0.058 N_3+0.100 N_4$	2.4
E		$0.679 N_1+0.317 N_2+0.079 N_3$	56.7**
M_1		$-0.177 N_2 \quad +0.056 N_4$	3.1*
M_2		$0.043 N_1+0.067 N_2-0.059 N_3+0.054 N_4$	1.3
M_3		$0.256 N_1-0.092 N_2+0.043 N_3-0.063 N_4$	8.1**
F_1	P_B (Depot fat)	$-0.173 N_1-0.090 N_2-0.054 N_3$	4.1
F_2		$0.161 N_1+0.013 N_2+0.030 N_3-0.069 N_4$	1.9
F_3		$0.196 N_1-0.041 N_2+0.027 N_3+0.014 N_4$	4.1*
E		$0.005 N_1-0.014 N_2-0.026$	0.1
M_2		$0.036 N_1+0.028 N_2+0.083 N^{\varepsilon}+0.206 N_4$	5.1**
F_1	P_C (Muscle size)	$0.297 N_1+0.242 N_2+0.186 N_3+0.104 N_4$	19.2**
F_3		$0.012 N_1+0.105 N_2+0.177 N_3+0.224 N_4$	9.2**
M_2	P_D (Head size)	$0.028 N_1+0.048 N_2+0.047 N_3+0.042 N_4$	0.7

* $P<0.05$

** $P<0.01$

In group E, the 10 nutrients, except vitamin D, were found to be effective to their body size, and its proportion, 56.7% was significant at the 1% level.

According to the proportion on the final column in Table 6, for the body size, there was the tendency of being greater in the groups of preschool and grade school children than in those above 12 years old, and the boys turned out to be almost twice as big as the girls. On the other hand, in the girls' group above 12 years of age, the proportion of the nutrient intake to the body size was low and not significant. As far as this survey revealed, these facts suggested that if children were exposed to the circumstances of limited nutritional status, incidence of undernutrition would appear severely younger boys below 11 years of age as a growth retardation before the other groups do.

In relation to the depot fat, components of nutrient intake did not affect it in group E. Among the six groups by sex and age, there were higher trends in the groups above 12 years of age than those in younger children for both sexes on the proportion. However, it was difficult to arrive at a definite conclusion due to the proportions.

As for the muscle size, it was observed that thiamine was effective for group M_2, all of the nutrients for group F_1, vitamines A and D, thiamine and ascorbic acid for group F_3. Among the 3 groups, M_2, F_1 and F_3, the proportions were significant at the 1% level respectively, and they showed higher ratios of the muscle size than those of the depot fat for the corresponding group.

In regard to the head size, the proportion of the multiple regression formula represented by the components of nutrients was low and not significant for group M_2.

Summarizing the results of multiple regression analysis, it was found that the nutrients taken by Hokkaido orphanage children in 1976 were mainly effective to the body size, and scarcely influenced the depot fat, in general.

The previous report[7,8] disclosed that the 1518 orphanage children compared with the national averages in 1976 showed that they were 97.7% in height and 95.8% in weight, and were 94% in energy and 86% in protein.

The physique of these children with limited height and weight could indicate less development of depot fat under circumstances of less energy and protein provided them which might lead to growth retardation.

The assumption that the growth retardation of the subjects due to their nutrient shortage was supported by the results of multivariate analyses.

Summary

In order to assess the nutritional status of growing children, the relationship between physique and dietary intake of orphanage children was explored by employing the methods of multivariate analyses.

Cross-sectional data, consisting of 11 anthropometric measures of the head and body besides 11 nutrient intakes, were collected concerning 1518 Hokkaido orphanage children between the ages of 1 and 18 years in 1976.

1. Variation: A) As to the physical characters, the tendency of the coefficient of variations was found to become greater in the following order: head size, trunk, limbs and skinfold. B) Concerning nutrient intake, vitamins A, D, thiamine and ascorbic acid showed wide differences, whereas the remainder, energy, protein, fat, calcium, iron, riboflavin and niacin equivalent, revealed a comparatively closer range.

2. Principal component analysis: A) In relation to the anthropometric data, the principal components extraction, accounting for 88% of the total variance and followed by varimax rotation, produced two orthogonal components for the entire subject; — whereas they were nearly 79–94% of the total variance and three or four varimax solutions for the six groups by sex and age. The compoents represent body size, depot fat, muscle size and head size. The first and second components were body size and depot fat respectively in the entire child as well as all of the boys and the grade-school girls grouped separately. As for both girls' groups, preschoolers and those over 12 years, the first and second components were depot fat and bodysize respectively. B) Regarding the nutrient intake, nearly 80% of the total variance was accounted for, after varimax rotation, producing three orthogonal components for the entire subjects. The first component was interpreted as a nutrient intake size including energy, protein, fat, calcium, iron, riboflavin, thiamine and niacin equivalent; the remainder, vitamins A, D and ascorbic acid were extracted in the second and third components. The six groups by sex and age were found to indicate the nutrient intake size as the first component with similarities as the entire child vitamins A, D, thiamine, riboflavin and ascorbic acid as the second, third and fourth components which showed different combinations, and to accumulate approximately 80–84% of total variance in four principal components extraction.

3. Multiple regression analysis: According to the results of this method performed by using the components score of the physique as dependent variables, and the score of the nutrient intake components as independent variables, the ten nutrients except vitamin D were found to be effective to

the body size, and its proportion was 56.7% in the entire subject. Depot fat was scarcely influenced by nutrient intake. The effects of such a tendency between the body size and the nutrient intake were greater in younger children below 11 years than older ones, and the boys turned out to be almost twice as big as the girls.

The previous report disclosed that the physique of these children with limited height and weight could indicate less development of depot fat under circumstances of less energy and protein provided them which might lead to growth retardation.

The assumption that the growth retardation of the subjects due to their nutrient shortage was supported by the results of multivariate analyses.

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