Age Change of Allometry Coefficients in Japanese

Komei HATTORI

*Department of Health and Physical Education,
Tokyo University of Agriculture and Technology*

Abstract Though allometry formula ($y=bx^{\alpha}$) is not influenced directly by the age, character of the age group sampled is predicted to be reflected on allometry coefficient. So the age changes of the allometry coefficient of body weight, chest girth and sitting height against stature were analyzed on the both sexes from 6 to 14 year-old. As allometry coefficients in each age were various even within the same stature class and show directional changes with ages, age definition should be required especially in the group of 12-14 year-old, because of marked variation of the coefficients in this period.

INTRODUCTION

Allometry equation was presented by HUXLEY and TEISSIER (1936) for indicating the relative growth and variation of the living thing, and was first tried to make use of for data of the human by THOMPSON (1938).

It was shown by many authors that the allometry equation is convenient for explaining the relationship between two measurements of the human (SHIMIZU, 1946; ALCOBE *et al.*, 1951; MORISHITA, 1969; KIMURA, 1970, and HATTORI *et al.*, 1971).

In general, allometry equation is indicated by areobic function, $y=bx^{\alpha}$, where x and y are variables, and b and α are constants. The component related to the time is not contained there. It owes to the idea that the growth should be considered as the function shown by variation of the growing material itself, because the meanings of the unit of time depends on the species of the living thing

or their growth level. But, it does not mean that the time factor can be ignored on the allometry growth analysis. As each age group is peculiar in distribution of dimension, the relative variation in each group may be predicted to be characteristic. And the peculiarity of age group will be reflected in the allometry coefficients. Indices also represent the relation between two measurements. ROHRER's index is known to be different with height levels or with ages even if within the same height levels (ICHIMURA, 1969).

In allometry analysis, though formula itself is not directly influenced by the age, character of the age group sampled is predicted to be reflected on relative growth coefficient.

Because of little attention having been paid on this problems hitherto, transition of the allometry coefficient with age will be discussed in the present paper.

MATERIALS AND METHODS

The data employed for the present studies are the correlation tables of stature and body weight, chest girth, and sitting height of both sexes from 6 to 14 year-old, cited from the "Statistical report on school health and hygiene on the 1968 school-year" published by Japanese Ministry of Education in 1970. Mean values of each item on every age and stature class are given in these tables. Table 1 shows the intervals and numbers of stature classes, and total sample sizes on each item. The stature is taken on the variable x and the mean value of the other items corresponding to each stature class is taken on the y of the allometry equation; $y=bx^a$. Heights taken on the abscissa as a marker of growth level, varied greatly with ages in the upper and lower limit ranges (Table 1).

Consequently, differences of the allometry coefficient in each age group, if existing, are not always indicating simply the differences relying on ages, but mainly caused by the differences of relative

growth level proper. To elucidate such problems, relative growth coefficients on the same stature range were compared among every age group.

Because common stature range through 6 to 14 year-old were not found, the ranges were divided into two sections; the class containing the range from 115 to 127 cm from 6 to 9 year-old, and from 138 to 154 cm from 10 to 14 year-old.

The allometry analyses concerning every stature class were also made after that. Allometry equation was calculated by the least square method, and other stochastic procedures owe to the general regression analysis.

RESULTS

1. Comparison of allometry coefficients within each section between the two stature classes

(a) Body weight: The α -values on the stature class 115-127 cm from 6 to 9 year-old seem to be gradually decreasing with

Table 1. Total sample sizes and range of stature in each age group
(BW: Body weight, CG: Chest girth, SH: Sitting height)

Age	Male					Female				
	Groups In Stature		Total Sample Size			Groups In Stature		Total Sample Size		
	Min-Max	N	BW	CG	SH	Min-Max	N	BW	CG	SH
6	100-132	33	9659	9664	9664	100-127	28	9240	9235	9241
7	105-135	31	9725	9728	9728	104-133	30	9468	9469	9469
8	110-139	30	9954	9923	9923	110-139	30	9631	9631	9631
9	115-145	31	10032	10003	10003	115-147	33	9857	9857	9857
10	118-154	37	9940	9993	9981	119-155	37	9799	9793	9793
11	124-160	37	10148	10148	10148	123-106	38	9978	9990	9990
12	128-167	40	8961	8961	8961	129-163	35	8753	8767	8767
13	133-174	42	9231	9231	9231	135-166	32	9037	9043	9043
14	138-178	41	9518	9515	9515	137-168	32	9205	9222	9222

Table 2. Age change of α and $\log b$ values of body weight. At the section of 6-9 and 10-14 year-old, the sample of stature range 115-127 cm and 138-154 cm are employed respectively.

Age	Male		Female	
	α	$\log b$	α	$\log b$
6	2.478 ± 0.234	-3.810	2.774 ± 0.437	-4.427
7	2.426 ± 0.106	-3.702	2.435 ± 0.188	-3.723
8	2.387 ± 0.036	-3.620	2.400 ± 0.193	-3.650
9	2.452 ± 0.231	-3.752	2.296 ± 0.150	-3.429
10	3.033 ± 0.492	-4.992	3.247 ± 0.418	-5.458
11	2.944 ± 0.099	-4.803	3.025 ± 0.131	-4.934
12	2.817 ± 0.099	-4.527	3.086 ± 0.059	-5.095
13	2.667 ± 0.100	-4.202	2.650 ± 0.262	-4.133
14	2.828 ± 0.150	-4.545	2.103 ± 0.379	-2.922

ages on female, and slightly decreasing or rather steady on male. The coefficient on 6 year-old male (2.478), shows apparently lesser value than on female (2.774), no dominant differences on 7 and 8 year-old, and in contrast greater on male (2.457) than female (2.296) on 9 year-old.

Concerning the α -values on the stature class 138-154 cm from 10 to 14 year-old, being larger on female (3.247) than on male (3.033) at 10 year-old, gradually decrease

ing on both sexes afterward to become obscure in sexual differences. The values on 13 year-old were 2.667 on male and 2.650 on female. On the other hand, the values at 14 year-old increase to 2.828 on male, while it apparently decrease to 2.103 on female.

(b) Chest girth: At the stature class 115-127 cm from 6 to 9 year-old, the allometry coefficients show significant decrease on 7 year-old female as compared with that on 6 year-old, but no remarkable

Table 3. Age change of α and $\log b$ values of chest girth. At the section of 6-9 and 10-14 year-old, the samples of stature range 115-127 cm and 138-154 cm are employed respectively.

Age	Male		Female	
	α	$\log b$	α	$\log b$
6	0.704 ± 0.107	0.304	0.804 ± 0.250	0.087
7	0.683 ± 0.024	0.350	0.691 ± 0.039	0.322
8	0.696 ± 0.041	0.326	0.670 ± 0.031	0.370
9	0.652 ± 0.074	0.420	0.680 ± 0.557	0.363
10	0.947 ± 0.123	-0.205	1.189 ± 0.257	-0.731
11	0.983 ± 0.056	-0.282	1.133 ± 0.063	-0.607
12	0.931 ± 0.054	-0.168	1.139 ± 0.059	-0.611
13	0.922 ± 0.047	-0.147	0.931 ± 0.124	-0.150
14	1.022 ± 0.143	-0.358	0.708 ± 0.116	0.321

ble changes afterwards. The coefficients concerning males are approximately 7.0 through the whole groups of stature. As shown in table 3, the sexual difference of α -value is distinguished only at 6 year-old (male:0.740, female:0.804).

At the stature class 138-154 cm from 10 to 14 year-old, transition of the coefficients on both sexes resembles those of body weight. Namely, α -values on female generally have a tendency of decrease, those from 10 to 12 year-old are representing positive allometry, and as a result of marked decrease, those on 13 to 14 are representing negative allometry. Marked change of α -value were not seen 10 to 13 year-old male. The values were between 0.9 and 1.0.

The value 0.992 at 13 year-old is much the same as the value on female (0.931) of the same age. As the value for 14 year-old male grows to 1.022, it becomes markedly larger than that of the same age female.

(c) Sitting height : Concerning the

groups of 6 to 9 year-old, differences of α -values depending on ages were not remarkable on both sexes. The differences depending on sexes were also not dominant.

On the group of 10 to 14 year-old, α -values on both sexes also represent negative allometry. On male, α -values gradually increase till 13 year-old and decrease afterwards. While those on female gradually increase till 12 year-old and decrease afterwards. On female, α -values were larger than on male at 12 year old. and it reversed at 13 and 14 year-old.

As mentioned above, allometry constants of body weight, chest girth, and sitting height in each age were varying even within the same stature class. Consequently, it is not always natural to understand the relative growth level to be equal even though within the group of a same stature range.

Such obvious variation of α -value in the certain group of age may not be restricted to be caused only by the differ-

Table 4. Age change of α and log b values of sitting height. At the section of 6-9 and 10-14 year-old, the sample of stature range 115-127 cm and 138-154 cm are employed respectively.

Age	Male		Female	
	α	log b	α	log b
6	0.878 $\pm$ 0.041	-0.001	0.900 $\pm$ 0.061	-0.047
7	0.870 $\pm$ 0.019	0.016	0.844 $\pm$ 0.014	0.071
8	0.844 $\pm$ 0.019	0.071	0.852 $\pm$ 0.004	2.030
9	0.891 $\pm$ 0.074	-0.029	0.874 $\pm$ 0.053	0.007
10	0.822 $\pm$ 0.077	0.113	0.911 $\pm$ 0.061	-0.075
11	0.858 $\pm$ 0.036	0.036	0.931 $\pm$ 0.009	-0.116
12	0.900 $\pm$ 0.013	-0.054	0.961 $\pm$ 0.029	-0.179
13	0.919 $\pm$ 0.024	-0.097	0.869 $\pm$ 0.047	0.022
14	0.822 $\pm$ 0.151	0.115	0.781 $\pm$ 0.079	0.217

ence of age. Because the same stature er ages, and lower part of stature groups class selected from every age means the on the elder ages, the specificity of such taller part of stature groups on the young- groups possibly be coming out on the α -

Table 5. Age change of α and log b values of body weight to stature.

Age	Male		Female	
	α	log b	α	log b
6	2.140±0.094	−3.108	2.233±0.104	−3.300
7	2.362±0.030	−3.568	2.429±0.216	−3.710
8	2.323±0.146	−3.478	2.435±0.040	−3.718
9	2.570±0.104	−3.998	2.608±0.106	−4.081
10	2.637±0.128	−4.137	2.682±0.123	−4.236
11	2.744±0.042	−4.137	2.797±0.090	−4.480
12	2.717±0.022	−4.309	2.915±0.040	−4.727
13	2.679±0.059	−4.223	2.491±0.143	−3.791
14	2.666±0.054	−4.192	1.955±0.387	−2.601

Table 6. Age change of α and log b values of chest girth to stature.

Age	Male		Female	
	α	log b	α	log b
6	0.598±0.176	0.524	0.627±0.049	0.455
7	0.595±0.096	0.534	0.668±0.039	0.373
8	0.699±0.062	0.321	0.725±0.047	0.258
9	0.749±0.051	0.218	0.828±0.067	0.042
10	0.737±0.081	0.247	0.911±0.081	−0.131
11	0.856±0.046	−0.007	0.986±0.016	−0.288
12	0.845±0.037	0.020	0.962±0.109	−0.230
13	0.914±0.025	−0.127	0.776±0.069	0.184
14	0.915±0.041	−0.126	0.655±0.069	0.460

Fig. 1. Graphic representation of allometry coefficients of body weight.

values. These specificity, if existing, will be able to elude by using whole stature group in each stature class.

2. Variation of allometry coefficients de-

Fig. 2. Graphic representation of allometry coefficients of chest girth.

pending upon ages

(a) Body weight (Table 5, Fig.1)

The coefficients on female are larger than those on male through 6 to 12 year-old, and become reversed afterwards because of remarkable decrease of them on female. The values, being steadier at 7 and 8 year-old, continuously increase till the maximum 2.915 on 12 year-old, and decrease afterwards till the minimum 1.955 at 14 year-old.

The α -values on male also keep increasing up to 11 year-old, though it stagnates at 7 and 8 year-old corresponding to female. It begins decreasing from 12 year-old, being one year earlier and more gentle than on female. The value at 14 year-old is 2.666.

(b) Chest girth (Table 6, Fig. 2)

The α -values on female from 6 to 12 year-old are also larger than those on male corresponding to the body weight, but they are reversed at 13 and 14 year-old. Decrease of α -values on female, beginning at 12 year-old, is remarkable on 13 and 14 year-old.

The values on female increase step-

wisely up to 11 year-old from marked negative allometry to isometry such as 0.672 at 6 year-old, 0.668 at seven, 0.725 at eight, 0.828 at nine, 0.911 at ten, and 0.986 at eleven. It begins decreasing thereafter and finally shows marked negative allometry 0.655 at 14 year-old.

On the other hand, the values on male repeat stagnation and increase with ages.

The maximum value 0.915, which is reached at 14 year-old, still shows negative allometry.

(c) Sitting height (Table 7, Fig. 3)

Variation of α -values on the sitting-height depending upon ages is not so conspicuous as the body weight and chest girth.

On male, α -values from 6 to 11 year-old are near 0.8 being slightly negative

Fig. 3. Graphic representation of allometry coefficients of sitting height.

Table 7. Age change of α and log b values of sitting height to stature.

Age	Male		Female	
	α	log b	α	log b
6	0.785 $\pm$ 0.040	0.192	0.819 $\pm$ 0.034	0.121
7	0.844 $\pm$ 0.037	0.070	0.811 $\pm$ 0.032	0.139
8	0.786 $\pm$ 0.057	0.191	0.819 $\pm$ 0.032	0.122
9	0.810 $\pm$ 0.291	0.140	0.837 $\pm$ 0.035	0.083
10	0.790 $\pm$ 0.049	0.183	0.865 $\pm$ 0.047	0.025
11	0.838 $\pm$ 0.024	0.080	0.859 $\pm$ 0.023	0.038
12	0.890 $\pm$ 0.041	-0.031	0.893 $\pm$ 0.020	-0.032
13	0.908 $\pm$ 0.029	-0.070	0.772 $\pm$ 0.055	0.234
14	0.909 $\pm$ 0.027	-0.071	0.755 $\pm$ 0.035	0.273

allometry. The values from 12 to 14 year-old are constantly around 0.9.

On female, the coefficients from 6 to 9 year-old also stagnate around 0.8. The values which are in accord with those on male are 0.837 at 9 year-old, 0.865 at ten, 0.859 at eleven, and 0.893 at twelve.

Thereafter the value is markedly reduces to 0.772 at 13 year-old, and represents minimum value 0.755 at 14 year-old. It is the common phenomenon through body weight, chest girth, and sitting height.

DISCUSSION

The allometry analyses of growth of individuals on the preadolescent period were reported by many authors (SHIMIZU, 1957; MORISHITA, 1969; KIMURA, 1970; and INOUE, 1964). The analyses of the trunk length, chest girth, body weight, and several measurements of physical fitness were performed by ASMUSSEN (1955) cross-sectionally. ALCOBE *et al.* (1951) reported the α -values on the length of upper limb, height to iliospinale, biacromial diameter and bicristal diameter from 7 to 14 year-old.

SHIMIZU and INOUE (1956) also reported the α -values of principal eleven items including body weight and head dimensions.

Since the concept of allometry growth is based upon the biological age, and the grade of age is explained by the quantity of the physical characteristics, the restriction of age has not been strictly considered in these studies. Even though within the groups which have similar

ranges of physical characteristics, the fact that the α -values show moderately clear directional changes with ages require allometry analysis among the near age groups.

As already shown by WETZEL (1943), even in growing stage, quantitative difference of physical character contains both difference of growing level and absolute size that come from hereditary factor.

Accordingly, though clear distinguishment of every age group is not required, more severe age definition should be required in the group of 12-14 year-old, because of marked variation of α -values in this period.

On the height and body weight of males and females, the α -values at 6 year-old were 2.14 and 2.23 respectively. These are lesser than 3.0 the theoretical value, in contrast to the values 3.12 on male and 3.24 on female on the fetal stage studied by MORITA and HATTORI (1968). But as clarified by WILMER *et al.* (1940) the composition of living body is not homogeneous and it is well known that the growth of the internal organs such as brain are not coincide with the items of SCAMMON's general type. It will consequently be estimated that the α -values of total body weight on adult is lesser than 3.0. HATTORI *et al.* (1971) reported that the allometry coefficients of adult Japanese (18 year-old) are 2.05 on male and 1.91 on female.

On the group of 6 year-old, the value is larger than those on adult, ratio of body weight accumulation is larger than on adult in the higher height group of

the same age group. This inclination is conspicuous with ages till 11 year-old on male and 12 year-old on female. The α -value grow steadily till 11 year-old on female, having the inclination of the higher the height the heavier the body weight.

The α -values on male begin decreasing after 11 year-old. It is presumed to be a process of approaching the value of adult (=2), though it should be mentioned after obtaining the values from 15 to 17 year-old. The phenomenon of decrease of α -values on female, which begins from one year later than on male, is very remarkable. The value at 14 year-old shows 1.95 which is almost equal to the value on adult. Whether the height-weight relation of allometry on female have already got the steady state at 14 year-old or not is depending upon the further studies concerning the data from 15 to 17 year-old as well as on male.

It is interesting that the process of the plots of allometry coefficients of chest girth is similar to that of body weight. The coefficients on male continue increasing to get near the value 1.0. On males from 6 to 14 year-old, the higher the height is, the smaller the chest girth is. It is presumed that increase of height on the elder age group possess increase of chest girth more conspicuously than on the younger group. The difference of physique depending on ages is presumed even among the samples of same heights.

The value on female shows isometry at 11 year-old, and they become smaller thereafter to show negative allometry a-

gain. This tendency of decrease begins one year earlier than the case of body weight. Each stature class is considered to have same ratio of chest girth as height at 11 year-old. However, thereafter the higher the height becomes, the smaller the chest girth is. This quality becomes marked with ages.

Considering the results on female with body weight, they become slenderer after 13 year-old as higher the height becomes. The phenomenon of becoming slenderer seemingly owes to the fact that lengthening is preceded to the other items of growth.

On sitting height, it is also interesting like body weight and chest girth that the values on female markedly decrease after 12 year-old. It is reasonable that the values of sitting height to the height expressing a tendency of slight negative allometry, since the ratio of head dimensions, which show SCAMMON's neural type, occupy the major part of the measurements.

Through the ages of 6 to 14 year-old on both sexes, the higher the height is, the smaller the ratio of sitting height is. The fact that this inclination is conspicuous at 13 and 14 year-old on female is considered to be related with the period of lengthening. Further the fact that the increase of sitting height is not accompanied by height increase seems to indicate the superiority of lower limb on growth. Consequently decrease of α -values in body weight and chest girth is not caused by the quantitative decrease or stagnation of body weight and chest girth, but is seemingly caused by de-

crease of comparative values by the more conspicuous increase of height.

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アロメトリー係数の年齢的变化

服 部 恒 明

東京農工大学一般教育部保健体育学教室

アロメトリー式 ($y = bx^a$) は、成長を成長系自体の状況の関数として示しており、時間の項を含まない。しかし、身長等により示される相対成長段階が等しい場合でも、年齢による差が想定されるため、6～14 歳の男女の身長に対する体重、胸囲、座高の相対成長係数を各年齢ごとに算出し、その年齢的变化について検討した。

まず各年齢間の相対成長段階の相違を除去するため、各年齢から同一身長階級の集団の描出を試みたが、全年齢に適合する身長の範囲は存在しなかったため、6～9 歳群では、身長 115～127 cm の集団につき、10～14 歳群では身長 135～154 cm の集団につき、アロメトリー係数の群内の比較を実施した。その結果、両群とも、各項目で一定の方向性をもつ顕著な年齢差や性差が認められた。

年齢差が示されたため、人差的な描出をすることなく、各年齢の全ての資料により、アロメトリー係数を求め、年齢に伴う経過をプロットした結果、各項目で共通した傾向が観察された。すなわち 6～11 歳までは、概ね係数は女が男より大きく、座高が停滞するのを除いて一定した増加を続ける。その後、女では各項目とも 13～14 歳で著しい減少がみられ、男女のアロメトリー係数の大小関係は逆転する。

このように年齢に伴いアロメトリー係数は方向性をもって明瞭に変化するという事実から、近似した年齢集団についての相対成長の検討が望ましいものと思われる。