Skeletal Maturity in Twins

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Abstract Skeletal maturation was analyzed in 1072 radiographs of the right hand and wrist in 458 pairs of identical twins and 78 pairs of fraternal twins, aged 12 to 18 years. Because skeletal maturity is already completed in the older children, the age groups of 12-14 years in boys and 12 years in girls were mainly discussed. Skeletal maturity was assessed by the K score, TW1 and TW2 methods, and heritability was evaluated by intrapair correlation, percent deviation and revised percent deviation, heritability indices, F-ratio and genotypic-environmental ratios. As regards estimation of heritability, all the skeletal scores and ages assessed by various methods showed high significant correlations with one another, and skeletal maturation suggested a high heritability which is almost the same in both sexes.

INTRODUCTION

Skeletal maturation is now of major interest as a biological yardstick of development not only for clinicians but also for investigators. PRYOR (1907), in a study of carpal sequence variation in sibships, was the first to suggest that variations in the ossification of bones were inherited, which was confirmed in his later studies (1936, 1939). From studies of the sequence of the ossification process in five sets of triplets (BUSCHKE, 1935), in fifty pairs of twins, four sets of quadruplets (KEY, 1936) and in five pairs of twins and nine sets of triplets (RIGLER, 1938), it was found that, while general growth and rate of ossification were to be regarded as being controlled by genetic factors, individual qualitative variations in the ossification

and in the form of the complete bones were likewise determined by genetic factors. REYNOLDS (1943), in an investigation on six pairs of twins, twenty-two pairs of siblings, eight pairs of first cousins and nine pairs of unrelated children, showed that identical twins had the highest concordance in sequence, followed by siblings, first cousins, and finally unrelated pairs of children, and he suggested that heredity operated upon both time and order of ossification centers. GARN and his colleagues, in studies of twins (GARN, ROHMANN and APFELBAUM, 1961; GARN, ROHMANN and ROBINOW, 1961; HERTZOG, FALKNER and GARN, 1969) and of pairings of parent-child (GARN and ROHMANN, 1962a; GARN, ROHMANN and DAVIS, 1963), concluded that most variations in ossification sequence and order and in ossification rate and timing were genetically determined. On

the other hand, PARKIN, NELIGAN, DEE and SIMPSON (1969), in a study of radiographs of the knee and ankle of forty-one pairs of twins taken within 72 hours of birth, suggested that intra-uterine nutrition played an important part in determining the age at which ossification centers became visible on a radiograph and affected greatly the actual size of the centers at birth, while genetic differences and to a lesser extent sex differences also affected the latter.

KIMURA (1962), on the basis of radiographs of the hand and wrist in sixty pairs of identical and fourteen pairs of fraternal twins at the age of 12.0–12.9 years, reported that inspectional intrapair differences of ossification in each phalanx of the third finger, the third metacarpal and carpal bones were found in 28.3% of identical twins and 78.6% of fraternal twins. The best known method of measuring maturity in hand and wrist bones is the inspectional method developed by GREULICH and PYLE (1959), but ACHESON (1954, 1957) pointed out some disadvantages of an inspectional method such as theirs, and proposed a scoring method, the so-called "Oxford method" for assessing skeletal maturity. KIMURA (1972) also devised a scoring method (K score method) based on the idea of ACHESON (1954). TANNER and his colleagues published a new system for assessing skeletal maturity which was later called the TW1 method (TANNER and WHITEHOUSE, 1959; TANNER, WHITEHOUSE and HEALY, 1962). TANNER, WHITEHOUSE, MARSHALL, HEALY and GOLDSTEIN (1975) revised it as the TW2 method. SKŁAD

(1973), in a study of fifty pairs of identical twins and forty-five pairs of fraternal twins aged 8 to 16 years, used the TW1 method and found that variation in the skeletal maturation process is conditioned mainly by genetic factors and that the rate of skeletal maturation of girls is conditioned by genetic factors to a greater extent than that of boys.

Partial X-chromosomal involvement in postnatal development timing was first found in teeth (GARN, LEWIS and POLACHECK, 1960; GARN and ROHMANN, 1962b; GARN, LEWIS and KERESKY, 1965) and later in hand-wrist. It has been estimated that the larger proportion of genetically determined variance in postnatal ossification timing may be attributed to genes on the X chromosome (GARN and ROHMANN, 1962b, 1966; GARN, ROHMANN and DAVIS, 1963; GARN, ROHMANN and HERTZOG, 1969). GARN and MCCREERY (1970) pointed out that, although absolute variability in postnatal ossification timing is generally larger in boys than in girls, relative, conception-corrected variability is significantly larger in girls, suggestive of a "dosage" effect and consistent with the hypotheses of partial X-linkage.

This study is part of a comprehensive study taken by the research group of twins in Japan. In the present paper, variation in ossification is discussed based on intrapair resemblance and difference in identical and fraternal twins and unrelated pairs of children, using different methods for assessing skeletal maturity.

MATERIALS AND METHODS

A series of 1072 radiographs of the right hand and wrist in 235 male and 223 female pairs of identical twins and 41 male and 37 female pairs of fraternal twins aged 12 to 18 years was studied between 1954 and 1965. All the subjects belonged to a socioeconomic class above the middle level in Tokyo. The radiographs were longitudinally taken every year in the spring for six years on 63 male and 70 female pairs of identical twins and 25 male and 21 female pairs of fraternal twins at the Junior and Senior High Schools attached to the Department of Education, University of Tokyo. Since some children left the school at various ages, the records were not complete for every one. For example, only 11 male and 10 female pairs of identical twins and one female pair of fraternal twins were longitudinally investigated for five years between the ages of 12 and 16 years. The diagnosis of the zygosity of each pair of twins was made by some members of the research group on the basis of a resemblance diagnosis method derived mainly from ESSEN-MÖLLER's formula (1941) (INOUE, 1956, 1962).

Radiographs of the hand and wrist were taken with the tube-film distance of 80 cm centred above the head of the third metacarpal. For assessing skeletal maturity, the K score (KIMURA, 1972), TW1 (TANNER *et al.*, 1962) and TW2 (TANNER *et al.*, 1975) methods were used. The K score, the TW1 and TW2 bone ages and the RUS and CARP ages (TW2 method) were assessed for each child by the author

alone. Commonly used analysis of variance tests are the F-ratio originated by DAHLBERG (1926) and HOLZINGER's heritability index (H^2) (HOLZINGER, 1929) with various modifications. According to WETHERINGTON and RUTENBERG (1978), while anova in general and heritability in particular have been criticized for having been both misapplied and misinterpreted, their proper application can provide valid estimates of the relative genotypic-environmental contributions to observed phenotypic variation. As a matter of fact, no such direct measure is possible in any case for data obtained on twins only (VANDENBERG, 1962). Intrapair resemblance is usually expressed as a coefficient of correlation and intrapair difference as a percent deviation ($PD = 100 [|A - B| / |A + B|]$, v. VERSCHUER, 1927) or an intrapair variance ($V = 1/n \sum [A - B]^2$). Recently, HOSHI, TAKAHASHI, ASHIZAWA and KOUCHI (1980) devised a revised percent deviation ($RPD = \sqrt{PD/CV}$) and a coefficient of similarity ($CS_{RPD} = /n$). The heritability index (H^2) was obtained by means of the following formulae; $(r_E - r_Z)/(1 - r_Z)$ (HOLZINGER, 1929), $1 - V_E/V_Z$ (CLARK, 1956), $2(r_E - r_Z)$ (BULMER, 1970) and $1 - (1 - r_E^2)/(1 - r_Z^2)$ (WETHERINGTON and RUTENBERG, 1978), while the F-ratio is calculated only from the formula, V_Z/V_E (DAHLBERG, 1926). The genotypic-environmental ratio is expressed by formulae, $(PD_Z - PDE)/PDE$ (v. VERSCHUER, 1927) or $(CS_Z - CSE)/CSE$. In these formulae, identical twins are expressed as the E (monozygotic) and fraternal ones as the Z (dizygotic). In the present paper, unrelated pairs of children (expressed as

the R) composed of one of each pair of twins are also discussed with the twins.

RESULTS

Table 1 gives the means ($\bar{x}$) and standard deviations (s) of the skeletal scores and ages based on each assessing method for one of each pair in identical and fraternal twins aged 12 to 18 years for both sexes separately. Each age (α_i) group includes the children aged $\alpha_{i-1}.6$ to $\alpha_i.5$ years. The K score of 100 in both sexes, the TW1 ages of 19 years for boys and 17 years for girls, and the TW2 ages of 18 and 16 years, the RUS ages of 18.2 and 16 years and the CARP ages of 15 and 13 years for each sex, respectively, are corresponded to the completion of maturation according to each method of assessing

skeletal maturity. In the table, the expression "adult" indicates that all the samples have reached complete maturation. The raised numbers "1" to "3" show that one child or more has completed skeletal maturation in the group, and that a child or both children within a pair have completed maturation in a half or more of the pairs in the group, respectively. These expression and raised numbers have the same meaning in subsequent tables. In each assessing method, the skeletal age is somewhat greater than the chronological age in each age group for both sexes. It is also found that girls generally mature skeletally earlier by about 2 years than boys. Figure 1 shows the sequential changes of the TW2 ages for each child of a pair in 11 male and 10 female identical

Table 1. Means ($\bar{x}$) and standard deviations (s) of the skeletal scores and ages for one of each identical and fraternal twin pairs aged 12 to 18 years.

Sex	Age(yrs.)	n	K score		TW1(yrs.)		TW2(yrs.)		RUS(yrs.)		CARP(yrs.)	
			$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Males	12	41	73.6	6.40	13.1	1.41	12.9	1.46	12.8	1.40	13.1	1.50 ¹
	13	34	79.6	6.82	14.3	1.19	14.0	1.38	14.1	1.38	14.0	1.25 ²
	14	48	86.4	5.66	15.6	1.05	15.4	1.01	15.5	1.05	14.8	0.48 ³
	15	46	91.3	4.37	16.5	6.16	16.3	6.08 ¹	16.5	6.56 ¹	adult	
	16	41	94.3	3.42	17.3	0.95	17.0	0.95 ²	17.3	0.94 ²	adult	
	17	45	96.8	2.42 ¹	18.0	0.73 ¹	17.6	0.63 ²	17.9	0.52 ²	adult	
	18	21	98.3	1.54 ²	18.4	0.50 ²	17.9	0.24 ³	18.1	0.22 ³	adult	
Females	12	29	86.3	5.77	13.6	1.10	13.2	1.15 ¹	13.5	1.27 ¹	12.8	0.68 ³
	13	39	91.0	4.29	14.5	0.83	14.1	1.02 ¹	14.6	1.00 ¹	adult	
	14	51	94.2	3.35	15.1	0.82	15.0	0.98 ¹	15.2	0.86 ¹	adult	
	15	42	96.7	1.70 ¹	15.9	0.52 ¹	15.8	0.56 ³	15.9	0.33 ³	adult	
	16	38	98.0	1.40 ¹	16.3	0.49 ¹	16.0	0.11 ³	16.0	0.08 ³	adult	
	17	45	98.9	1.30 ²	16.6	0.44 ²	16.0	0.01 ³	16.0	0.02 ³	adult	
	18	18	99.6	0.69 ³	16.9	0.23 ³	adult		adult		adult	

Note : ¹ = a child or more complete the skeletal maturation
² = a child within a pair completes the skeletal maturation in a half or more pairs
³ = both in a pair complete the skeletal maturation in a half or more pairs

Fig.1. Sequential changes of the TW2 skeletal age in identical twins aged 12 to 16 years based on longitudinal data. Sexes and pair numbers are shown on the left. Circles and dotted circles show the skeletal ages for each one of a pair of twins at the chronological ages 12 to 16 years. A fine line connects children of a pair at the same chronological age.

Table 2. Coefficients of correlation (r) within pairs of twins and unrelated children aged 12 to 18 years for skeletal score and ages.

Age (yrs.)	Sex & zygosity	No. of pairs	K score	TW1 age	TW2 age	RUS age	CARP age
12	ME	27	0.94 **	0.98 **	0.96 **	0.96 **	0.97 ** ¹
	MZ	14	0.74 **	0.75 **	0.69 **	0.78 **	0.57 * ¹
	MR	20	-0.10	0.11	0.00	0.06	-0.01 ¹
	FE	21	0.98 **	0.97 **	0.96 ** ¹	0.97 ** ¹	— ³
	FZ	8	0.23	0.08	0.10	-0.02	adult
	FR	14	0.46	0.41	0.30 ¹	0.35 ¹	— ³
13	ME	26	0.97 **	0.98 **	0.97 **	0.97 **	— ³
	MZ	8	0.42	0.03	-0.02	0.11	0.00 ²
	MR	17	0.01	-0.02	-0.01	0.22	-0.15 ²
	FE	29	0.91 **	0.98 **	0.97 ** ¹	0.97 ** ¹	— ³
	FZ	8	0.84 *	0.85 *	0.73 *	0.76 *	adult
	FR	18	-0.35	-0.23	0.02 ¹	-0.21 ¹	adult
14	ME	43	0.97 **	0.98 **	0.98 **	0.98 **	— ³
	MZ	5	0.68	0.87	0.75 ¹	0.69 ¹	adult
	MR	24	-0.48	-0.12	0.01	-0.13	— ³
	FE	46	0.92 **	0.88 **	0.85 ** ¹	0.91 ** ¹	adult
	FZ	5	0.14	0.46	0.41 ¹	0.40 ¹	adult
	FR	25	-0.02	0.14	0.08 ¹	0.00 ¹	adult
15	ME	42	0.93 **	0.91 **	0.92 ** ¹	0.92 ** ¹	adult
	MZ	4	0.89	0.82	0.62	0.52	adult
	MR	23	0.10	-0.04	-0.07 ¹	-0.09 ¹	adult
	FE	39	0.95 ** ¹	0.95 ** ¹	— ³	— ³	adult
	FZ	3	†	†	adult	adult	adult
	FR	21	0.20 ¹	0.40 ¹	— ³	— ³	adult
16	ME	38	0.92 **	0.90 **	0.87 ** ²	0.87 ** ²	adult
	MZ	3	0.98	0.96	0.83 ²	0.92 ²	adult
	MR	20	-0.30	-0.33	-0.38 ²	-0.36 ²	adult
	FE	34	0.82 ** ¹	0.84 ** ¹	— ³	— ³	adult
	FZ	4	— ¹	— ¹	adult	adult	adult
	FR	19	0.32 ¹	0.31 ¹	— ³	— ³	adult
17	ME	40	0.95 ** ¹	0.94 ** ¹	— ³	— ³	adult
	MZ	5	0.92 * ¹	0.90 * ¹	— ³	— ³	adult
	MR	22	-0.05 ¹	-0.13 ¹	-0.14 ²	-0.12 ²	adult
	FE	38	— ³	— ³	— ³	— ³	adult
	FZ	7	0.61 ¹	0.61 ¹	adult	adult	adult
	FR	22	0.14 ²	0.12 ²	— ³	— ³	adult

Age (yrs.)	Sex & zygosity	No.of pairs	K score	TW1 age	TW2 age	RUS age	CARP age
18	ME	19	0.97 ** ¹	0.95 ** ¹	— ³	— ³	adult
	MZ	2	— ³	— ³	adult	adult	adult
	MR	10	- 0.05 ²	- 0.13 ²	— ³	— ³	adult
	FE	16	— ³	— ³	adult	adult	adult
	FZ	2	— ³	— ³	adult	adult	adult
	FR	9	— ³	— ³	adult	adult	adult

Note : M = male, F = female, E = identical, F = fraternal, R = random

** & * = significant at the levels of 1 and 5 %, respectively

† = the s is zero in a group within the pairs

¹ ~ ³ = see the note in Table 1

twins for five years from 12 to 16 years of age longitudinally. Only 3 out of 21 children (14.3%) shows no intrapair differences of the skeletal age for all five years. The intrapair differences seem to be observed at various ages and not particularly around a certain age. Of course, when they have completed skeletal maturity at the TW2 ages of 18 years in boys and 16 years in girls, no intrapair differences can be observed at any chronological age. In some pairs, one child within a pair does not always precede the other. These facts agree quite well with the results based on other methods for assessing skeletal maturity. Accordingly, it is suggested that, in the present sample, detailed discussion is generally possible for the age groups 12 to 14 years in boys and 12 years in girls, and that 14-years-old boys and 12-years-old girls could be comparable almost at the same level of skeletal maturation.

Table 2 gives the coefficients of intrapair correlation (r), and Table 3 the means ($\bar{x}$) and standard deviations (s) of the intrapair variance (V), percent deviation (PD) and revised percent deviation ($\bar{x}$ of RPD

= CS) for each skeletal score and age in the identical (E) and fraternal (Z) twins and the pairs of unrelated children (R). In Table 2, the single asterisk (*) and double asterisks (**) show the significant correlations at the level of 5% and 1%, respectively. Significant intrapair correlation is found in all the age groups of identical twins based on every assessing method. It is found only in the age groups of 12 and 17 years in boys and 13 years in girls in fraternal twins, and the pairs of unrelated children show no correlation in any groups. In identical twins, the coefficient of correlation ranges from 0.94 to 0.98 (unweighted mean from z transform of r is 0.974) for the K score (0.959) and the TW1 (0.980), TW2 (0.965) and RUS (0.965) ages at the ages 12 to 14 years in boys, and from 0.96 to 0.98 (on the average 0.969) for these scores and ages (0.98, 0.97, 0.96 and 0.97) at the age of 12 years in girls. In fraternal twins, the average coefficient of correlation for all the skeletal scores and ages is 0.604 in boys aged 12 to 14 years, and 0.099 in girls aged 12 years. The identical twins

Table 3. Means ($\bar{x}$) and standard deviations (s) of the variance (V), percent deviation (PD) and revised percent deviation (coefficient of similarity) (CS) within pairs of twins and unrelated children aged 12 to 18 years for skeletal score and ages.

Skeletal maturity	Age (yrs.)	Sex & zygosity	No. of pairs	V		PD		CS	
				$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
K score	12	ME	27	2.9	5.34	0.85	0.9592	0.26	0.1828
		MZ	14	34.3	60.07	2.77	2.7717	0.49	0.2839
		MR	20	90.1	128.53	4.88	4.3065	0.68	0.3311
		FE	21	1.8	2.73	0.51	0.5537	0.22	0.1698
		FZ	8	21.3	21.44	2.30	1.4385	0.44	0.1742
		FR	14	40.4	62.04	2.83	2.7519	0.58	0.3012
	13	ME	26	3.1	6.37	0.67	0.9238	0.21	0.1817
		MZ	8	84.8	154.39	4.05	4.9869	0.57	0.3761
		MR	17	103.2	118.45	5.55	3.3711	0.74	0.2366
		FE	29	2.8	8.11	0.47	0.8336	0.21	0.2387
		FZ	8	6.6	7.93	1.21	0.8982	0.32	0.1334
		FR	18	48.1	77.28	3.00	3.5186	0.74	0.3107
	14	ME	43	1.5	4.17	0.45	0.6275	0.20	0.1701
		MZ	5	25.2	43.04	2.37	2.1316	0.55	0.2421
		MR	24	72.1	131.68	3.58	3.4699	0.67	0.3213
		FE	46	2.0	4.23	0.46	0.6079	0.26	0.2511
		FZ	5	2.8	2.81	0.75	0.5184	0.43	0.1816
		FR	25	23.1	30.15	2.05	1.6488	0.68	0.3448
	15	ME	42	2.4	5.68	0.47	0.7308	0.24	0.2390
		MZ	4	10.8	9.55	1.57	1.0323	0.57	0.2353
		MR	23	28.9	48.71	2.40	1.7695	0.69	0.2692
		FE	39 ¹	0.4	0.91	0.14	0.2852	0.15	0.2452
		FZ	3	0.8	1.30	0.26	0.4503	0.37	0.1290
		FR	21 ¹	4.7	6.33	0.83	0.7864	0.54	0.4306
	16	ME	38	1.6	4.92	0.37	0.5750	0.23	0.2307
		MZ	3	1.3	1.43	0.53	0.3118	0.37	0.1090
		MR	20	29.6	38.64	2.35	1.7715	0.80	0.3279
		FE	34 ¹	0.5	0.92	0.21	0.3865	0.19	0.3211
		FZ	4 ¹	0.6	1.13	0.19	0.3800	0.18	0.3645
		FR	19 ¹	3.1	3.50	0.67	0.6052	0.54	0.4386
	17	ME	40 ¹	0.6	1.33	0.20	0.3469	0.16	0.2358
		MZ	5 ¹	2.0	3.40	0.47	0.6994	0.27	0.3770
		MR	22 ¹	12.1	13.76	1.52	1.0167	0.72	0.2983
		FE	38 ³	—	—	—	—	—	—
		FZ	7 ¹	1.3	3.40	0.22	0.5745	0.15	0.4071
		FR	22 ²	2.9	3.66	0.63	0.6129	0.52	0.4630

Skeletal maturity	Age (yrs.)	Sex & zygosity	No. of pairs	V		PD		CS	
				$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
K score	18	ME	19 ¹	0.1	0.52	0.06	0.1798	0.09	0.1889
		MZ	2 ³	—	—	—	—	—	—
		MR	10 ²	5.5	5.62	0.93	0.7839	0.63	0.4681
		FE	16 ³	—	—	—	—	—	—
		FZ	2 ³	—	—	—	—	—	—
		FR	9 ³	—	—	—	—	—	—
TW1	12	ME	27	0.05	0.1048	0.55	0.6617	0.16	0.1607
		MZ	14	1.48	2.4103	3.65	3.3694	0.53	0.2482
		MR	20	3.57	5.6276	5.72	5.0091	0.67	0.2960
		FE	21	0.08	0.1376	0.68	0.7693	0.22	0.1896
		FZ	8	0.41	0.4961	1.91	1.4252	0.32	0.1969
		FR	14	1.58	2.7111	3.39	3.8322	0.55	0.3514
	13	ME	26	0.08	0.2393	0.50	0.9226	0.32	0.1926
		MZ	8	5.84	10.1167	6.22	7.5265	0.70	0.4714
		MR	17	3.41	4.0690	5.16	4.2464	0.68	0.3325
		FE	29	0.08	0.2366	0.52	0.8624	0.20	0.2296
		FZ	8	0.14	0.1568	1.11	0.7682	0.29	0.1485
		FR	18	1.51	2.9150	3.17	2.6928	0.71	0.3240
	14	ME	43	0.05	0.1065	0.41	0.5873	0.17	0.1880
		MZ	5	0.72	0.6943	2.41	1.3188	0.59	0.1653
		MR	24	2.36	3.0212	3.54	0.4642	0.63	0.3790
		FE	46	0.16	0.3242	0.77	1.0814	0.25	0.2798
		FZ	5	0.38	0.3831	1.58	1.4174	0.49	0.2453
		FR	25	1.18	1.5685	2.92	2.2617	0.66	0.3220
	15	ME	42	1.02	4.0580	0.71	1.0215	0.24	0.2429
		MZ	4	0.45	0.3298	1.82	1.0933	0.51	0.2060
		MR	23	2.05	3.0614	3.47	2.6943	0.64	0.1838
		FE	39 ¹	0.04	0.0984	0.31	0.5874	0.15	0.2693
		FZ	3	0.48	0.8114	1.56	2.7020	0.40	0.6886
		FR	21 ¹	0.35	0.4700	1.28	1.3886	0.46	0.4353
	16	ME	38	0.26	0.7153	0.79	1.2048	0.28	0.2689
		MZ	3	0.07	0.0837	1.59	0.5630	0.27	0.2360
		MR	20	2.39	2.8294	3.76	2.5739	0.78	0.2870
		FE	34 ¹	0.05	0.1023	0.44	0.7741	0.20	0.3265
		FZ	4 ¹	0.06	0.1250	0.37	0.7450	0.17	0.3489
		FR	19 ¹	0.41	0.4559	1.50	1.3204	0.65	0.4155
	17	ME	40 ¹	0.07	0.1463	0.36	0.6421	0.16	0.2528
		MZ	5 ¹	0.35	0.3792	1.40	0.9607	0.52	0.3067
		MR	22 ¹	1.20	1.5610	2.50	1.8353	0.31	0.3079

Skeletal maturity	Age (yrs.)	Sex & zygosity	No.of paris	V		PD		CS	
				$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
TW1	17	F E	38 ³	—	—	—	—	—	—
		F Z	7 ¹	0. 14	0. 3780	0. 43	1. 1452	0. 15	0. 4004
		F R	22 ²	0. 25	0. 3612	1. 17	1. 1821	0. 49	0. 4441
	18	M E	19 ¹	0. 04	0. 0838	0. 23	0. 4695	0. 14	0. 2593
		M Z	2 ³	—	—	—	—	—	—
		M R	10 ²	0. 55	0. 6288	1. 49	1. 4087	0. 56	0. 4989
		F E	16 ³	—	—	—	—	—	—
		F Z	2 ³	—	—	—	—	—	—
		F R	9 ³	—	—	—	—	—	—
TW2	12	M E	27	0. 13	0. 3835	0. 73	1. 2486	0. 16	0. 2030
		M Z	14	2. 18	4. 0137	4. 12	4. 3023	0. 53	0. 2836
		M R	20	4. 29	6. 3836	6. 31	5. 4833	0. 67	0. 2836
		F E	21 ¹	0. 12	0. 2337	0. 78	1. 0232	0. 21	0. 2225
		F Z	8	0. 42	0. 5480	1. 96	1. 7536	0. 33	0. 1962
		F R	14 ¹	2. 33	4. 2568	4. 14	4. 5413	0. 58	0. 3771
	13	M E	26	0. 08	0. 2871	0. 43	0. 9891	0. 10	0. 1812
		M Z	8	6. 64	10. 4050	6. 93	7. 8937	0. 66	0. 5053
		M R	17	4. 66	5. 8251	5. 77	5. 1161	0. 67	0. 3820
		F E	29 ¹	0. 09	0. 2258	0. 53	0. 9594	0. 15	0. 2256
		F Z	8	0. 21	0. 2278	1. 44	1. 0416	0. 31	0. 1599
		F R	18 ¹	1. 94	2. 5500	4. 01	2. 3961	0. 70	0. 2699
	14	M E	43	0. 05	0. 0772	0. 42	0. 5646	0. 18	0. 1991
		M Z	5 ¹	1. 10	0. 9952	3. 08	1. 5115	0. 68	0. 1654
		M R	24	2. 96	2. 8622	3. 47	2. 9599	0. 66	0. 3299
		F E	46 ¹	0. 30	0. 6153	1. 04	1. 5028	0. 26	0. 3011
		F Z	5 ¹	0. 61	0. 6701	2. 12	1. 6509	0. 52	0. 2474
		F R	25 ¹	1. 77	2. 4497	3. 43	3. 0621	0. 58	0. 3776
	15	M E	42 ¹	0. 17	0. 5131	0. 65	1. 0627	0. 21	0. 2465
		M Z	4	0. 46	0. 4436	1. 85	1. 1435	0. 53	0. 1835
		M R	23 ¹	2. 62	2. 4359	3. 41	2. 7451	0. 67	0. 3377
		F E	39 ³	—	—	—	—	—	—
		F Z	3 ^a	—	—	—	—	—	—
		F R	21 ³	—	—	—	—	—	—
	16	M E	38 ²	0. 19	0. 4892	0. 60	1. 1429	0. 19	0. 2735
		M Z	3 ²	0. 43	0. 4082	1. 51	1. 3423	0. 42	0. 3688
		M R	20 ²	2. 42	2. 4321	3. 92	3. 5653	0. 76	0. 3552
RUS	12	M E	27	0. 11	0. 2847	0. 73	1. 0797	0. 17	0. 1987
		M Z	14	1. 78	2. 3791	4. 14	3. 7485	0. 55	0. 2867
		M R	20	3. 79	6. 2425	5. 94	5. 2713	0. 68	0. 2977

Skeletal maturity	Age (yrs.)	Sex & zygosity	No. of pairs	V		PD		CS	
				$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
RUS	12	F E	21 ¹	0.14	0.2583	0.82	1.0117	0.22	0.2043
		F Z	8	1.17	1.4510	3.34	2.3429	0.51	0.2778
		F R	14 ¹	2.33	3.2663	4.41	4.0484	0.60	0.3316
	13	M E	26	0.11	0.2844	0.57	1.0608	0.13	0.1942
		M Z	8	6.32	11.3910	6.49	8.2111	0.66	0.4481
		M R	17	3.42	3.8133	5.47	3.8539	0.67	0.2791
		F E	29 ¹	0.14	0.2622	0.84	1.1254	0.24	0.2544
		F Z	8	0.56	0.5915	2.11	1.3487	0.52	0.2039
		F R	18 ¹	2.25	3.1886	4.42	3.1398	0.75	0.2801
	14	M E	43	0.03	0.0644	0.34	0.4687	0.15	0.1773
		M Z	5 ¹	1.67	2.0619	3.71	2.3771	0.73	0.2149
		M R	24	2.35	3.7290	3.73	3.2660	0.68	0.3215
		F E	46 ¹	0.15	0.2899	0.76	1.0080	0.25	0.2774
		F Z	5 ¹	0.16	0.1457	0.97	0.7552	0.44	0.1436
		F R	25 ¹	1.47	2.3057	2.93	3.0212	0.60	0.4066
	15	M E	42 ¹	0.20	0.4683	0.77	1.1384	0.23	0.2582
		M Z	4	0.91	0.9361	2.46	1.9278	0.56	0.2805
		M R	23 ¹	2.49	3.5476	3.89	2.8093	0.71	0.2923
		F E	39 ³	—	—	—	—	—	—
		F Z	3 ^a	—	—	—	—	—	—
		F R	21 ³	—	—	—	—	—	—
	16	M E	38 ²	0.20	0.4572	0.64	1.1286	0.20	0.2836
		M Z	3 ²	0.29	0.2482	1.32	0.8717	0.47	0.1928
		M R	20 ²	2.35	2.8085	3.67	2.6705	0.74	0.3600
CARP	12	M E	27 ¹	0.15	0.4184	0.80	1.4142	0.14	0.2272
		M Z	14 ¹	2.80	4.6058	4.62	5.0216	0.50	0.4004
		M R	20 ¹	4.59	6.6572	6.73	5.4053	0.68	0.3455
		F E	21 ³	—	—	—	—	—	—
		F Z	8 ^a	—	—	—	—	—	—
		F R	14 ³	—	—	—	—	—	—
	13	M E	26 ³	—	—	—	—	—	—
		M Z	8 ²	4.59	7.8891	4.99	6.9959	0.53	0.5756
		M R	17 ²	3.07	3.3847	5.25	4.7946	0.63	0.4658

Note : 1 ~ 3 = see the note in Table 1

a = adult in skeletal maturation

Table 3. appendix. Results of the t-test (asterisk) and Welch's test (dagger) for the means between two of each group. Only significant differences are recorded in the table.

Skeletal maturity	Age (yrs.)	Groups :	Boys			Girls		
			V	PD	CS	V	PD	CS
K score	12	E - Z	†	††	**	††	††	**
		E - R	††	††	††	††	††	††
	13	E - Z	†	—	††	**	*	—
		Z - R	—	—	—	—	—	††
		E - R	††	††	**	††	††	**
	14	E - Z	††	—	**	**	—	—
		E - R	††	††	††	††	††	**
	15	E - Z	*	**	*	—	—	—
		E - R	††	††	**	††	††	††
	16	Z - R	—	—	*	—	—	—
		E - R	††	††	**	††	††	††
	17	Z - R	—	—	*	*	—	—
		E - R	††	†	**	††	*	/
	18	E - R	††	—	—	**	—	**
TW1	12	E - Z	††	††	**	†	††	—
		E - R	††	††	††	†	††	††
	13	E - Z	††	††	††	—	—	—
		Z - R	—	—	—	—	—	††
		E - R	††	††	††	†	††	**
	14	E - Z	††	††	**	—	—	—
		E - R	††	—	††	††	††	**
	15	E - Z	—	*	*	††	†	—
		E - R	—	††	**	††	††	††
	16	Z - R	—	—	*	—	—	—
		E - R	††	††	**	††	††	**
	17	E - Z	†	**	**	—	—	—
		E - R	††	††	**	—	†	†
	18	E - R	††	†	††	—	—	—
TW2	12	E - Z	†	††	**	—	*	—
		E - R	††	††	††	†	††	††
		E - Z	††	††	††	*	*	—
	13	Z - R	—	—	—	—	†	**
		E - R	††	††	††	††	††	**
	14	E - Z	††	††	**	—	—	—
		E - R	††	††	††	††	††	**
	14	E - R	††	††	††	††	††	**

Skeletal maturity	Age (yrs.)	Groups :	Boys			Girls		
			V	PD	CS	V	PD	CS
TW2	15	E - Z	—	*	—	—	—	—
		E - R	—	††	**	††	†	—
	16	E - R	††	††	**	—	—	—
	17	E - R	††	††	††	—	—	—
RUS	12	E - Z	††	††	**	††	††	**
		E - R	††	††	**	††	††	**
	13	E - Z	†	††	**	††	*	**
		E - R	††	††	**	††	††	**
	14	E - Z	††	††	**	—	—	—
		E - R	††	††	**	††	††	**
	15	E - Z	†	*	*	—	—	—
		E - R	††	††	**	—	—	—
	16	E - R	††	††	**	—	—	—
		E - R	††	††	††	—	—	—
	12	E - Z	††	††	††	—	—	—
		E - R	††	††	††	—	††	—
CARP	13	E - Z	††	††	††	/	/	/
		E - R	††	††	††	/	/	/
	14	E - R	—	††	†	/	/	/
		E - R	—	††	†	/	/	/

Note : The Welch's test was used when variances differ significantly.

An asterisk (*) and a dagger (†) and double asterisks (**) and daggers (††) show the significant levels of 5 % and 1 %, respectively.

apparently show a higher intrapair correlation than the fraternal twins in both sexes. Appendix of Table 3 shows the results of the test for the means of each intrapair variance, percent deviation and revised percent deviation among the identical and fraternal twins and the pairs of unrelated children. The significant differences are shown with an asterisk (*) and double asterisks (**) based on the t-test, and, when the variances differ significantly, with a dagger (†) and double daggers (††) based on the WELCH's test, at the significant levels of 5% and 1%, respectively. The means of intrapair variance, percent deviation and revised percent

deviation show the lowest values in the identical twins, followed by the fraternal twins, and the highest ones in the pairs of unrelated children for every skeletal score and age, with a few exceptional age groups just before the completion of maturation. In general, the significant differences of the means are almost always found between the identical twins and the pairs of unrelated children, frequently between the identical and fraternal twins and only in a few age groups between the fraternal twins and the unrelated pairs.

Table 4 gives the values of HOLZINGER's (H^{2a}), BULMER's (H^{2b}), WETHERINGTON & RUTENBERG's (H^{2c}) and CLARK/CAVALLI-

Note: 1~3=see the note in Table 1

$$H^{2a} = (r_E - r_Z) / (1 - r_Z) \text{ (HOLZINGER, 1929)}$$

$$H^{2b} = 2(r_E - r_Z) \text{ (BULMER, 1970)}$$

$$H^{2c} = 1 - (1 - r_E^2) / (1 - r_Z^2) \text{ (WETHERINGTON & RUTENBERG, 1978)}$$

$$H^{2d} = 1 - V_E / V_Z \text{ (CLARK, 1956; CAVALLI-SFORZA & BODMER, 1971*)}$$

$$F\text{-ratio} = V_Z / V_E \text{ (DAHLBERG, 1926; CLARK, 1956; WETHERINGTON & RUTENBERG, 1978*)}$$

$$G/E^a = (PD_Z - PD_E) / PDE \text{ (v. VERSCHUER, 1927)}$$

$$G/E^b = (CS_Z - CS_E) / CSE \text{ (this series)}$$

* their formulae differ one another, but mean the same value.

SFORZA & BODMER's (H^{2d}) heritability indices, DAHLBERG/CLARK/WETHERINGTON & RUTENBERG's F-ratio and v. VERSCHUER's (G/E^a) and revised (G/E^b) genotypic-environmental ratios, calculated from the values in Tables 2 and 3. The values may be meaningless in some age groups except those of 12 and 13 or 14 years, because of the small number of the fraternal twins in addition to the above-mentioned reasons. From Table 4, a high heritability is apparently suggested in skeletal scores and ages. Picking up only the age group of 14 years in boys and 12 years in girls, the means of heritability indices for four skeletal score and ages (K score, and TW1, TW2 and RUS ages) are 0.9084 for boys and 0.9668 for girls in the H^{2a} , 0.4691 and 1.7463 in the H^{2b} , 0.8951 and 0.9488 in the H^{2c} , and 0.9577 and 0.8284 in the H^{2d} , respectively. The heritability index is generally less than 1, except for the BULMER's index (H^{2b}). The value is higher in girls than in boys in every index, except for the value of the CLARK/CAVALLI-SFORZA & BODMER's index (H^{2d}), at least at these ages. However, the means of F-ratio are 26.0805 for boys and 7.2568 for girls, and those of genotypic-environmental ratios are 6.2919 and 2.4713 in the G/E^a , and 2.7163 and 0.8457 in the G/E^b ,

for each sex, respectively. Accordingly, these values are possibly higher in boys than in girls.

On the other hand, in boys, the mean heritability index is 0.8400 for the score, 0.7105 for the TW1 age, 0.8094 for the TW2 age and 0.875 for the RUS age. In girls, it is 1.0850, 1.1262, 1.0799 and 1.1902 for each score and age, respectively. The value is higher in girls than in boys for every skeletal score and age. While the value is higher for the RUS age, followed by those for the K score and TW2 age, than for the TW1 age in boys, it is high in the order of the means for the RUS and TW1 ages, the K score and the TW2 age in girls. The means of two genotypic-environmental ratios are 2.8972 for the K score, 3.6743 for the TW1 age, 4.555 for the TW2 age and 6.8893 for the RUS age in boys, and in girls, it is 2.2549, 1.1317, 1.0552 and 2.1956 for each score and age, respectively. The F-ratio and mean genotypic-environmental ratio are higher in boys than in girls for every skeletal score and age. The ratio is high in the order of the values for the RUS, TW2 and TW1 ages and the K score in boys, while in girls, it is the highest for the K score, followed by the RUS and TW1 ages, and the lowest for the TW2

Table 5. Correlation matrix of the various heritability values of the skeletal maturation based on some assessing methods.

		Boys (12 yrs.)						
		H ² ^a	H ² ^b	H ² ^c	H ² ^d	F	G/E ^a	G/E ^b
Boys (13 yrs.)	H ² ^a	—	0. 6844 *	0. 9984 **	0. 2922	0. 7908 *	0. 0599	0. 8228 **
	H ² ^b	0. 4722	—	0. 6445	— 0. 4881	0. 1214	0. 3084	0. 5507
	H ² ^c	0. 9271 **	0. 6472	—	0. 3414	0. 8184 *	0. 1108	0. 8295 **
	H ² ^d	0. 9428 **	0. 3416	0. 9365 **	—	0. 7596 *	0. 9329 **	0. 2557
	F	0. 9437 **	0. 2412	0. 8883 **	0. 9906 **	—	0. 5054	0. 5571
	G/E ^a	0. 8750 **	0. 0174	0. 7578 *	0. 9347 **	0. 9727 **	—	0. 2045
	G/E ^b	0. 4680	— 0. 4491	0. 1228	0. 3900	0. 5114	0. 6676	—
		Boys (14 yrs.)						
		H ² ^a	H ² ^b	H ² ^c	H ² ^d	F	G/E ^a	G/E ^b
Girls (12 yrs.)	H ² ^a	—	0. 9609 **	1. 0000 **	0. 8214 **	0. 6703 *	0. 6331	0. 4617
	H ² ^b	0. 0591	—	0. 9599 **	0. 6458 *	0. 4627	0. 4021	0. 2031
	H ² ^c	0. 7777 *	— 0. 4648	—	0. 8335 **	0. 6718 *	0. 6345	0. 4625
	H ² ^d	0. 8434 **	— 0. 1733	0. 5922	—	0. 9032 **	0. 0261 **	0. 8500 **
	F	0. 6634 *	— 0. 4174	0. 5340	0. 9510 **	—	0. 9872 **	0. 9466 **
	G/E ^a	0. 6717 *	— 0. 2123	0. 3975	0. 9632 **	0. 9735 **	—	0. 9778 **
	G/E ^b	0. 3888	0. 2738	— 0. 1495	0. 7047 *	0. 6678 *	0. 8150 *	—

Note : An asterisk (*) and double asterisks (**) show the significant correlations at the level of 5 % and 1 %, respectively.

age.

Table 5 gives the correlation matrix of the heritability values, F-ratio and genotypic-environmental ratios for the skeletal maturation based on five assessing methods in the age groups of 12, 13 and 14 years in boys and of 12 years in girls. In general, it seems that there are no or few correlations between the H^{2b} and F, the H^{2b} and G/E^a and the H^{2b} and G/E^b, followed by between the H^{2a} and G/E^b, the H^{2b} and H^{2a}, the H^{2b} and H^{2c}, the H^{2b} and H^{2d}, the H^{2c} and G/E^a, and the H^{2c} and G/E^b, compared to the others. From the correlation matrix, it seems that the H^{2b} (BULMER) and G/E^b are more different, followed by the H^{2c} (WETHERINGTON & RUTENBERG), G/E^a (V. VERSCHUER), than the F (DAHLBERG/CLARK/WETHERINGTON

& RUTENBERG), as well as the H^{2a} (HOLZINGER) and H^{2d} (CLARK/CAVALLI-SFORZA & BODMER), from the others. On the other hand, there are high correlations between the H^{2d} and G/E^a, the H^{2d} and F, the H^{2a} and H^{2c}, the H^{2a} and F, followed by between the H^{2a} and H^{2d}, the H^{2c} and F, the H^{2c} and H^{2d}, and the F and G/E^a, compared to the others. From these results it seems that the H^{2a} (HOLZINGER) and H^{2d} (CLARK/CAVALLI-SFORZA & BODMER) show higher correlations, followed by the H^{2c} (WETHERINGTON & RUTENBERG), F (DAHLBERG/CLARK/WETHERINGTON & RUTENBERG) and G/E^a (V. VERSCHUER), than the G/E^b and H^{2b} (BULMER), with the others.

Table 6 gives the correlation matrix of the heritability of each skeletal score and age based on various heritability indices

Table 6. Correlation matrix of the heritability of each skeletal score and age based on various heritability values.

		Boys (12 yrs.)				
		K score	TW1 age	TW2 age	RUS age	CARPage
Boys (13 yrs.)	K score	—	0. 9988 **	0. 9931 **	0. 9914 **	0. 9941 **
	TW1 age	0. 9685 **	—	0. 9968 **	0. 9954 **	0. 9979 **
	TW2 age	0. 9748 **	0. 9984 **	—	0. 9998 **	0. 9996 **
	RUS age	0. 9734 **	0. 9986 **	0. 9999 **	—	0. 9989 **
	CARP age	/	/	/	/	—
		Boys (14 yrs.)				
		K score	TW1 age	TW2 age	RUS age	
Girls (12 yrs.)	K score	—	0. 9990 **	0. 9992 **	0. 9911 **	
	TW1 age	0. 9773 **	—	0. 9989 **	0. 9898 **	
	TW2 age	0. 9488 **	0. 9921 **	—	0. 9949 **	
	RUS age	0. 9948 **	0. 9812 **	0. 9632 **	—	

Note : Double asterisks (**) shows the significant correlations at the 1 % level.

and ratios in the same age groups as Table 5. All the skeletal scores and ages based on different methods show apparently high significant correlations with one another.

DISCUSSION

Many authors have pointed out that identical twins have the highest concordance in sequence of ossification process or that most variations in skeletal maturation are genetically determined (PRYOR, 1907, 1936, 1939; BUSCHKE, 1935; KEY, 1938; RIGLER, 1938; REYNOLDS, 1943; GARN *et al.*, 1961a, 1961b, 1962, 1963; KIMURA, 1962; HERTZOG *et al.*, 1969; SKŁAD, 1973). According to GARN, ROHMANN and DAVIS (1963), both for ossification rate (number of centers present at a given age) and ossification timing (age at appearance of individual centers) correlations increase from parents and their children (circa 0.3) through siblings (0.4–0.6) to identical twins (0.88 in rate and 0.96 in timing).

On the basis of the TW1 skeletal ages in 18 male and 12 female pairs of identical twins and 14 male and 21 female pairs of fraternal twins, aged 8 to 16 years, SKŁAD (1973) has reported that the intrapair correlation is 0.967 for boys and 0.829 for girls in identical twins and 0.520 and 0.526 for each sex in fraternal twins, respectively. In the present study, it is 0.980 for boys and 0.88 for girls in identical twins for the TW1 age in the age groups of 12–14 years in boys and 12 years in girls. On the average of the correlation for all skeletal scores and ages, it is 0.974 in boys and 0.969 in girls of identical twins and 0.604 in boys and 0.099 in girls of fraternal twins. Unrelated pairs of children do not show any correlation for them. The intrapair correlation is clearly higher in the identical twins, followed by the fraternal ones, than random pairs of unrelated children, as previous authors reported. According to SKŁAD (1973), the

F-ratio is 13.872 in boys and 44.701 in girls, and also the H^{2d} (CLARK/CAVALLI-SFORZA & BODMER) is 0.928 and 0.978 in each sex, respectively. In the present study, the F-ratio is 39.069 in boys and 5.125 in girls, and the H^{2d} is 0.9619 and 0.8024 in each sex, for the TW1 age in the groups of 12-14 years in boys and 12 years in girls. Summing up all the skeletal scores and ages, the F-ratio is 30.573 in boys and 7.257 in girls, and the H^{2d} is 0.9479 and 0.8284 in each sex, in the same age groups. Both results are almost similar for these ratios and indices, especially for the heritability index. GARN *et al.* (1962, 1963, 1966, 1969, 1970) have suggested a "dosage" effect in skeletal maturation. SKLAD (1973) has also supported this fact from his results that both F-ratio and heritability index are higher in girls than in boys, though the intrapair correlation shows a reversed result in identical twins. However, in the present study, while three kinds of heritability index (H^{2a} , H^{2b} and H^{2c}) are generally higher in girls than in boys, CLARK/CAVALLI-SFORZA & BODMER's index (H^{2d}), F-ratio and genotypic-environmental ratios are higher in boys rather than in girls. The H^{2a} , H^{2b} and H^{2c} are calculated from the coefficient correlations in identical and fraternal twins. The intrapair correlation is also slightly higher in boys than in girls in the identical twins of this series.

As a matter of fact, no direct measure is possible to estimate the heritability of phenotypic characters in any case for data obtained on twins only. Among the indices and ratios used in the present study,

it seems that the BULMER's index (H^{2b}) and G/E^b ratio are somewhat different from the others as an index of heritability. On the other hand, the HOLZINGER's (H^{2a}) and CLARK/CAVALLI-SFORZA & BODMER's (H^{2d}) indices show high correlations with the other indices and ratios

In the present study, the following conclusions are found as regards the skeletal maturation revealed by the K score and the TW1, TW2 and RUS ages in Japanese identical and fraternal twins and unrelated pairs of children aged 12-14 years in boys and 12 years in girls: the intrapair correlation is higher in identical twins than in fraternal twins and unrelated pairs of children, being about 0.97 in both sexes. The means of heritability indices for four skeletal scores and ages is 0.9605 in boys and 0.9668 in girls in the HOLZINGER's index, and 1.6848 and 1.7463 in the BULMER's, 0.8875 and 0.9398 in the WETHERINGTON & RUTENBERG's and 0.9591 and 0.8284 in the CLARK/CAVALLI-SFORZA & BODMER's indices in each sex, respectively. The means heritability index is 1.1095 in boys and 1.1203 in girls, and is 0.9177 in boys and 0.9116 in girls, when the BULMER's index is excluded. The DAHLBERG/CLARK/WETHERINGTON & RUTENBERG's F-ratio is 33.5668 in boys and 7.2568 in girls, the genotypic-environmental ratio by percent deviation (V. VERSCHUER) 7.0346 and 2.4713, and the same ratio by revised percent deviation 2.6038 and 0.8475 in each sex, respectively. Some of these values agree well with those reported previously by many authors. Heritability estimated from these values is not

necessarily higher in girls than in boys. Although it is higher in girls than in boys based on the HOLZINGER's, BULMER's and WETHERINGTON & RUTENBERG's heritability indices, it is rather clearly higher in boys than in girls based on the CLARK/CAVALLI-SFORZA and BODMER's heritability index, DAHLBERG/CLARK/WETHERINGTON & RUTENBERG's F-ratio, genotypic-environmental ratios by percent deviation (v. VERSCHUER) and revised percent deviation. From these results, it may be suggested that skeletal maturation revealed by the skeletal scores and ages showed a high heritability, but that the "dosage" effect in skeletal maturation was not confirmed. As regards estimation of heritability, all the skeletal scores and ages assessed by various methods (K score, TW1, TW2 and RUS methods) showed apparently high significant correlations with one another.

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ふたごの骨格成熟

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12～18歳の458組の一卵性と78組の二卵性双生児の合計1072枚のX線写真を基に，K法，TW1法とTW2法による骨格年齢による骨格成熟の遺伝性が，対内相関係数，百分率偏差，百分率偏差（改），遺伝性指数，F比と遺伝・環境比から考察された。手部骨格は高年齢児ではすでに成熟を終っているので，男では12～14歳，女では12歳の資料を中心に検討されている。各方法による骨格年齢の成績は相互に高い相関を示し，男女とも同様の高い遺伝性を示唆している。