POSSIBILITIES OF DETERMINATION OF GENETIC CONDITIONINGS OF SOMATIC AND FUNCTIONAL TRAITS ON THE BACKGROUNDS OF FAMILY STUDIES: THE REVIEW OF RESULTS OF COMPARISON OF FIVE POLISH POPULATIONS

by

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The aim of the study was an attempt to explain the reasons of interpopulational differentiation of family resemblance's determining by methods arising from variance analysis. Five populations from Poland (1700 families) were compared, in which the same methods of r and h^2 estimations were used.

The attempted generalization of results have been made on the basis of „ranking" the values heritability indices in particular populations, as well as determining the mean „position" of given trait in „hierarchy" of theirs genetic conditionings strength in the total material.

It was found, that high interpopulation variability in family resemblances and genetic control strength of particular traits result from the different: environmental variance, assortative mating rate and genotype-environmental variance Thus, in the case of examination of only one population, concluding has to be limited only to this population, and only in relative terms (weaker-stronger). Generalisations may only be done when the hierarchy of genetic conditionings is compared in many populations. The thesis has been confirmed of relatively low diagnostic value of the heritability index, which suggests the necessity of supplementing it with complementary methods. General regularities have been determined on shaping the genetic control strength for various traits in both sexes and in various periods of ontogenesis. Out of 11 traits analysed, body height and co-ordination abilities showed relatively high genetic control, V_{O2max}, MAP and movement speed – average and body weight, relative muscular strength, flexibility, reaction time and FM – weak. The genetic factor showed increasing importance with age, with inter-sex differences and the so-called „puberty wobbling" of much less importance.

Key words: population genetic, heritability, quantitative traits, functional development.

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The problem of assessing the genetic control strength over the development of the human being is still open. The examinations conducted so far followed two main methods: the twins method and the family resemblance method. They yield results, which are often diverse and difficult to compare. This is due to many factors, basically, however, it seems that the responsibility falls on major simplifications made in the interpretation of sources of quantitative features phenotype variation, on which all the methods are based. Thus, may we remind here that this variation is made up of the elements provided in the following formula (Falconer 1974):

$$V_t = V_a + V_d + V_{i_{g\text{-}g}} + V_{i_{g\text{-}e}} + V_{e_g} + V_{e_r} + V_{e_s}$$

The additive variation *(V_a)*, the domination variation *(V_d)*, the genetic interaction variation *($V_{i_{g\text{-}g}}$)* (between genes in different locus, e.g. pleiotropy, epistasis, etc.), the genotype – environment interaction variation *($V_{i_{g\text{-}e}}$)*, the long-term environmental effects variation *(V_{eg})*, the short-term environmental effects variation *(V_{e_r})*, and the measurement error variation V_{e_s}. The sum of V_a + V_d + $V_{i_{g\text{-}g}}$ is usually considered in its totality as the *(V_g)* genetic variation, while V_{e_g} + V_{e_r} as the V_e – environmental variation. The so-called heritability index (h^2, H) constructed on this basis is intended to determine the ratio (portion) of the genetic variation to the V_t total variation.

If this simplification is to be used, then $h^2 = \frac{V_g}{V_t}$; however, if $V_t = V_g + V_e$, then the index shall have the form of:

$$h^2 = \frac{V_g}{V_g + V_e}$$

As we can see, its value depends actually on the V_e value (!), thus it is rather a measure of **ecosensitivity** (we often forget that it was construed by the animal genetics researchers, who call it the "breeding value"). It seems that it is **the first cause** resulting in high discrepancies of results obtained in various populations (for example, one could expect that in environmentally "homogeneous" populations, e.g. the poor, h^2 shall be higher than in the more varied populations, like the richer or the city ones). **The second cause** is not taking into account in many a research of the effect of assortative mating (between the parents), which increases the parents – children similarity (Fisher 1918, Susane 1976) and which differs in populations. **The third cause** lies in omitting some components of the genetic variation, especially of V_d and $V_{ig\text{-}g}$ (data are needed here on both the parents – children similarities and between siblings, while we cannot determine the genetic interaction). Due to obvious reasons, this similarity leads in the fact that results of twins examination always give higher indices than examinations of family similarities: the twins method determines $h^2 = \frac{V_g}{V_t}$ (inheritance in a "wide sense"), with the "family" method determining $h^2 = \frac{V_a}{V_t}$ (inheritance in a "narrow sense"). **The fourth cause** is inherent to the methodology. It happens (more and more rarely, it's true) that intra-family correlations are calculated with "raw" values, which makes it impossible to select differences in variation of different traits and of population differences (the scale of changes in the parent population is different than in the children population). Thus, **standardisation** of individual values is necessary here within groups of at least age and sex: only such results are comparable. We shall not forget about obvious interpretation difficulties, which result from examining different sets of traits with different tests!

This paper aims at several purposes. One of these is to prove the effect of the specific nature of the examined population upon the values of family similarities, which means the effect of differing environmental variation. Another, of not lesser importance, is to prove that the genetic control strength for particular traits may only be analysed **within the given population**, and **only in the stronger vs. weaker terms**, not according to specific numerical data. The third goal is to present relative "weakness" of the intra-family correlation method, from which the necessity to supplement them with additional methods follows. One of these shall be presented in the final part of the article. And last but not least, the fourth goal is to make an attempt at generalising detailed results in order to assess the actual genetic control strength for various traits.

Material and Methods

The results of examinations of family similarities have been selected as the material for this paper in five populations: two of Krakow city, examined in

1981-1983 (Szopa and al. 1985) and 1982-1989 (Mleczko 1991: the only continuous examination), two of Kielce (town – 200 000 cit.), examined in 1992-1996 (Jopkiewicz 1998) and in 1995-1996 (Ciesla) and one of Zywiec country population (Szopa and Jaworski 1998). These examinations meet the requirement for the necessary "minimum" size in intra-family relationships (several dozen to several hundred), cover a broad range of age, take into account assortative mating, and the correlations are calculated for standardised values. The group covers over 1,700 families in total, which will enable some generalisation of results.

Comparisons between populations have also been made for both values adjusted with correlation indices (in the four major relation types: father – child, mother – child, parents – son, and parents – daughter), as well as heritability indices calculated uniformly according to the formula of: $h^2 = 2c_{corr}$ (C_{corr} – the parents – children correlation coefficients adjusted for assortative mating), in three age groups, which reflect the major ontogenesis stages: 7 – 10, 11 – 14 and 15 – 19 years. The attempted generalisation of results have been made on the basis of "ranking" the values of heritability indices in particular populations and arriving at "mean points" (the place of a given traits within all the examined ones) and calculating the average h^2 values for particular traits, which will allow determining the probable hierarchy of their genetic control strength.

The comparisons cover 11 traits (abilities), both somatic and functional. Obviously enough, this list is not always a complete one, which has been taken into account when the results were ranked.

Results and Discussion

Assortative mating

The values for the father – mother correlation coefficients are given in Table 1; they have been referenced also against the selected (average) data presented by Bouchard and al. (1997) and Wolanski and al. (1991). As one can see, only the somatic traits show similar values in various populations (e.g. the body height: 0.21 – 0.28, with the exception of the country population, in which they are at the lowest of 0.19, which is probably due to the limited "mating radius" still present in the rural milieu). There are significant differences between specific motor abilities, e.g. reaction time from 0.00 to 0.32, V_{O2max} from 0.08 to

0.38, MAP from 0.01 to 0.32, and in this case they are lower for the rural population (probably due to a more unified lifestyle). Generally speaking, the correction scale for the parents – children correlation is varied: from 0.00 to 0.09, which is a significant value (when calculating h^2, this value is doubled).

Table 1. Father – mother correlation indices in various populations

TRAIT	RESEARCH						
	Krakow 81–83	Krakow 81–89	Kielce 92–96	Kielce 95–9	Żywiecczyzna 95–97	Bouchard &Malina 1997 (selected)	Wolański 1975–1978
Body height	0,24	0,26	–	0,28	0,14	–	0,21
Body mass	0,26	0,12	–	0,17	0,22	–	0.04
Fat mass	0,27	0,24	–	0,26	0,05	–	0,16
Simple reaction time	0,08	0,00	0,19	–	0,32	0,01	0,26
eye-movement co-ordinat.	0,11	0,08	–	0,20	0,25	0,21	0,15
HR (V_{O2max})	0,02	-0,08	–	–	–	0,20	0,38
Relative strength	0,12	0,14	0,17	0,15	0,15	0,12	0,10
MPA	0,12	0,01	0,32	0,15	0,12	0,06	0,10
Balance	–	–	–	0,10	-0,11	–	0,08
Flexibility	-0,04	-0,02	–	-0,07	0,03	-0,09	0,20
Movement speed	–	0,16	0,36	0,16	0,14	0,15	0,23

Table 2 presents the values of adjusted correlation coefficients for particular traits in the five populations being compared. The first observation is the **incompleteness** of data, which results from the varied set of examined features and varied age of children; this is probably the best illustration of the state of research in the human population genetics in Poland.

Comparing the "r" value shows **immense inter-population differentiation**, especially for functional traits. The most "stable" are family similarities of the body height (ranged from 0.2 to 0.4, *apart from extreme cases*). The *most* labile are: reaction time (0.07 – 0.31), movement speed (– 0.01 – 0.37), MAP

(0.00 – 0.36) and flexibility (0.06 – 0.40). The relations are also very differentiated within particular consanguinity types and age groups. In some cases, correlation coefficients are higher between fathers and children, in majority of cases, the effect of the mother is stronger, though. In majority of cases, the relationships with parents are stronger for sons than for daughters, which usually applies to functional traits (apart from flexibility). The increasing value of correlation coefficients with age is almost the rule: this phenomenon is present mostly with boys and applies to reaction time, eye-movement co-ordination, movement speed, relative strength, MAP and flexibility. These results seem to support the current views on the influence of the mother's genotype: the "maternal regulator" problem (Wolanski 1968) and the effect of the mitochondrial DNA transferred only by the oocyte (Dionne and al. 1991) are both included here. The higher similarity to parents present in the functional traits of sons than of daughters result probably from incomplete execution of the genotype in girls (Szopa and al. 1996) due to their reduced motor activity. The problem of diminishing family similarities in the puberty period, which is often quoted, is only partially proved in the examined cases, and this almost exclusively for the body height and for related traits (relative strength, MAP). Thus, it seems that this regularity does not apply to functional traits. This evidently proves different growth tracks (Szopa and al 1996) for somatic and functional features and their independent genetic determination.

Table 3 presents the values of heritability indices in comparable populations. They prove the regularities presented above, exposing the huge inter-population differentiation in the genetic control strength even more for its specific features, along with its dependency on age and sex. As the collected data are so illegible, the apparently only way out was applied, namely ranging specific features in particular populations according to their "h^2 hierarchy" in two age groups only, that is 7 – 14 and over 15 years (see Tab. 4). This allows a relative assessment (the only allowed) in the "stronger – weaker" terms. As one can see, the ranking variations are very significant: even the body height, which is commonly known as a traits subject to the strong genetic control, occupies places from 1 to 4, with the body weight ranking as 1 to 8, and the ranking range for functional features is immense (e.g. visual and motor co-ordination from 1 to 7, movement speed from 1 to 8, MPA from 1 to 9, flexibility from 1 to 10). Also, sex differences and relationships changing with age are visible.

Table 2. Inter – family correlation indices in comparable populations

TRAIT	AGE	KRAKOW 81-83				KRAKOW 81-89 (LONGIT.)				KIELCE 92-96				KIELCE 95-96				ŻYWIECCZYZNA 95-97			
		f–ch (341)	m-ch (681)	p-s (330)	p-d (592)	f-ch (150)	m-ch (150)	p-s (148)	p-d (150)	f-ch	m-c	p-s	p-d	f-ch (205)	m-ch (205)	p-s (91)	p-d (114)	f-ch (218)	m-ch (218)	p-s (250)	p-d (186)
Body height	7-14	0,22	0,17	0,21	0,16	0,24	0,29	0,32	0,20					0,17	0,30	0,25	0,21	0,30	0,43	0,44	0,23
	11-14	0,20	0,29	0,28	0,25	0,19	0,23	0,18	0,21					0,42	0,22	0,30	0,16	0,26	0,41	0,38	0,24
	15-19	0,38	0,35	0,29	0,38	-	-	-	-					0,41	0,21	0,39	0,24	-	-	-	-
Body mass	7-14	0,13	0,18	0,21	0,12	0,28	0,17	0,15	0,30					0,10	0,31	0,17	0,24	0,18	0,22	0,29	0,08
	11-14	0,14	0,17	0,11	0,14	0,26	0,17	0,14	0,30					0,12	0,20	0,16	0,18	0,17	0,12	0,09	0,22
	15-19	0,15	0,21	0,09	0,19	-	-	-	-					0,25	0,26	0,37	0,16	-	-	-	-
Fat mass	7-14	-0,05	0,21	0,21	0,04	-	-											0,16	0,17	0,17	0,18
	11-14	0,15	0,17	0,18	0,08	-	-											0,33	0,15	0,22	0,27
	15-19	0,13	0,10	0,04	0,09	-	-											-	-	-	-
Simple reaction time	7-14	0,07	0,08	0,07	0,09	0,15	0,12	0,20	0,10	0,15	0,15	0,15	0,14					0,14	0,09	0,15	0,11
	11-14	0,13	0,09	0,17	0,04	0,10	0,14	0,12	0,12	0,21	0,15	0,19	0,17					0,22	0,11	0,36	-0,12
	15-19	0,20	0,08	0,13	0,12	-	-	-	-	0,31	0,27	0,29	0,28					-	-	-	-
eye-mov. co-ord.	7-14	0,37	0,11	0,24	0,13	0,19	0,16	0,14	0,21					0,12	0,11	0,12	0,11	0,35	0,24	0,18	0,41
	11-14	0,35	0,29	0,41	0,20	0,18	0,17	0,17	0,19					0,27	0,29	0,19	0,37	0,21	0,25	0,30	0,12
	15-19	0,32	0,22	0,32	0,24	-	-	-	-					0,23	0,42	0,29	0,39	-	-	-	-
Move-ment speed	7-14					0,11	0,13	0,06	0,16	0,31	0,18	0,22	0,27	0,06	0,02	0,01	0,05	0,16	-0,01	0,10	0,04
	11-14					0,15	0,11	0,03	0,22	0,23	0,19	0,19	0,24	0,10	0,11	0,17	0,07	0,19	0,18	0,18	0,18
	15-19					-	-	-	-	0,26	0,30	0,25	0,32	0,13	0,37	0,37	0,12	-	-	-	-

Table 2

HR (V_{O2max})	7-14	0,16	0,13	0,12	0,16	0,22	0,22	0,29	0,15												
	11-14	0,14	0,14	0,21	0,08	0,20	0,18	0,26	0,12												
	15-19	0,21	0,31	0,43	0,21	-	-	-	-												
Relative strength	7-14	0,11	0,08	0,11	0,08	0,12	0,18	0,16	0,13	0,10	0,15	0,17	0,03	0,12	0,01	0,12	0,02	0,19	0,11	0,14	0,01
	11-14	0,22	0,16	0,21	0,17	0,10	0,16	0,11	0,14	0,14	0,00	0,13	0,01	0,21	0,46	0,30	0,36	0,12	0,17	0,15	0,14
	15-19	0,16	0,12	0,16	0,12	-	-	-	-	0,22	0,26	0,23	0,25	0,33	0,29	0,11	0,50	-	-	-	-
MAP	7-14	0,14	0,17	0,19	0,12	0,12	0,18	0,16	0,13	0,15	0,15	0,14	0,11	0,06	0,12	0,16	0,02	0,14	0,26	0,33	0,00
	11-14	0,21	0,18	0,23	0,16	0,10	0,16	0,11	0,14	0,24	0,26	0,23	0,26	0,23	0,19	0,30	0,20	0,10	0,11	0,13	0,10
	15-19	0,33	0,28	0,36	0,25	-	-	-	-	0,35	0,33	0,34	0,32	0,13	0,03	0,13	0,04	-	-	-	-
Balance	7-14													0,14	0,04	0,03	0,14	-0,07	0,08	0,18	0,41
	11-14													0,15	0,21	0,32	0,07	0,08	0,24	0,30	0,12
	15-19													0,31	0,38	0,39	0,30	-	-	-	-
Flexi-bility	7-14	0,08	0,12	0,06	0,14	0,11	0,13	0,06	0,16					0,38	0,22	0,40	0,20	0,07	0,10	0,02	0,17
	11-14	0,11	0,14	0,07	0,18	0,15	0,11	0,03	0,22					0,20	0,20	0,31	0,14	0,12	0,23	0,21	0,17
	15-19	0,13	0,19	0,11	0,21	-	-	-	-					0,14	0,30	0,18	0,23	-	-	-	-

Table 3. Comparison of h^2 values in comparable populations.

TRAIT	AGE	KRAKOW 81-83			KRAKOW 82-89			KIELCE 92-96			KIELCE 95-96			ŻYWIECCZYZNA 95-97		
		s.	d	gener.	s	d.	gener.	s	d	gener.	s	d	gener.	s	d.	gener.
Body height	7-10	0,42	0,32	0,37	0,64	0,40	0,52				0,50	0,42	0,46	0,88	0,46	0,67
	11-14	0,56	0,50	0,53	0,36	0,42	0,39				0,60	0,72	0,66	0,76	0,48	0,62
	15-19	0,58	0,76	0,67	-	-	-				0,78	0,58	0,68	-	-	-
Body mass	7-10	0,42	0,34	0,38	0,30	0,60	0,45				0,34	0,48	0,41	0,58	0,16	0,37
	11-14	0,22	0,28	0,25	0,28	0,60	0,39				0,32	0,36	0,34	0,18	0,44	0,31
	15-19	0,18	0,38	0,28	-	-	-				0,74	0,32	0,53	-	-	-
Fat mass	7-10	0,42	0,08	0,25										0,34	0,36	0,35
	11-14	0,36	0,16	0,26										0,44	0,52	0,49
	15-19	0,08	0,18	0,13										-	-	-
Simple reaction time	7-10	0,14	0,18	0,16	0,40	0,20	0,30	0,30	0,28	0,29				0,30	0,22	0,26
	11-14	0,34	0,08	0,21	0,24	0,24	0,24	0,38	0,34	0,36				0,72	-0,24	0,24
	15-19	0,26	0,24	0,25	-	-	-	0,54	0,58	0,56				-	-	-
Eye-mov. co-ord.	7-10	0,48	0,26	0,37	0,28	0,42	0,35				0,24	0,22	0,23	0,36	0,82	0,59
	11-14	0,82	0,40	0,61	0,34	0,38	0,36				0,38	0,74	0,56	0,60	0,24	0,42
	15-19	0,64	0,48	0,56	-	-	-				0,58	0,78	0,68	-	-	-
Movement speed	7-10				0,12	0,32	0,22	0,44	0,54	0,49	0,02	0,10	0,06	0,20	0,08	0,14
	11-14				0,06	0,42	0,24	0,38	0,48	0,43	0,34	0,14	0,24	0,36	0,36	0,36
	15-19				-	-	-	0,50	0,64	0,57	0,74	0,24	0,49	-	-	-
HR (V_{O2max})	7-10	0,24	0,32	0,28	0,58	0,30	0,44									
	11-14	0,42	0,16	0,29	0,52	0,24	0,38									
	15-19	0,86	0,42	0,74	-	-	-									
Relative strength	7-10	0,22	0,16	0,19	0,32	0,26	0,29	0,34	0,06	0,20	0,24	0,04	0,14	0,28	0,02	0,15
	11-14	0,42	0,34	0,38	0,22	0,28	0,25	0,26	0,02	0,14	0,60	0,72	0,66	0,30	0,28	0,29
	15-19	0,32	0,24	0,28	-	-	-	0,46	0,50	0,48	0,22	1,00	0,61	-	-	-
MAP	7-10	0,38	0,24	0,31	0,32	0,26	0,29	0,28	0,22	0,25	0,32	0,04	0,18	0,66	0,00	0,33
	11-14	0,46	0,32	0,39	0,22	0,28	0,25	0,46	0,52	0,49	0,40	0,40	0,40	0,26	0,20	0,23
	15-19	0,72	0,50	0,61	-	-	-	0,68	0,64	0,66	0,26	0,08	0,17	-	-	-
Balance	7-10										0,06	0,28	0,17	0,36	0,82	0,59
	11-14										0,64	0,14	0,39	0,60	0,24	0,42
	15-19										0,78	0,60	0,69	-	-	-
Flexibility	7-10	0,12	0,28	0,20	0,12	0,32	0,22				0,80	0,40	0,60	0,04	0,34	0,19
	11-14	0,14	0,36	0,25	0,06	0,44	0,25				0,62	0,28	0,40	0,42	0,34	0,38
	15-19	0,22	0,42	0,31	-	-	-				0,36	0,46	0,41	-	-	-

Table 4. Range rankings for heritability indices for particular features in comparable populations.

TRAIT	AGE	KRAKOW 81-83		KRAKOW 82-89		KIELCE 92-96		KIELCE 95-96		ŻYWIEC 95-97		TOTAL (AVERAGE POINTS & RANK)	
		sons	daught.	sons	daught.	sons	daught.	sons	daught.	sons	daught.	sons	daught.
Body height	7-14	2	1	2	2			2	1	1	3	1,75 **1**	1,75 **1**
	15-x	4	1	-	-			1	4	-	-	2,5 **1**	2,5 **1**
Body mass	7-14	5	3	5	1			6	3	6	6	5,5 **9**	3,25 **3**
	15-x	8	6	-	-			3	6	-	-	5,5 **6**	6 **8**
Fat mass	7-14	4	9							6	4	5 **7**	6,5 **9**
	15-x	9	9							-	-	?	?
Simple reacion time	7-14	8	8	3	9	3	3			2	10	4 **4**	7,5 **11**
	15-x	6	8	-	-	2	3			-	-	4 **4**	5,5 **7**
Eye-mov. co-ord	7-14	1	2	4	3			7	2	3	1	3,7 **3**	2 **2**
	15-x	3	3	-	-			5	2	-	-	4 **4**	2,5 **1**
Movement speed	7-14			8	5	1(!)	1	8(!)	8	8	7	6,2 **10**	5,25 **6**
	15-x			-	-	3	1	3	7	-	-	3 **2**	4 **4**
HR (V_{O2max})	7-14	5	7	1	6							3 **2**	6,5 **9**
	15-x	1	4	-	-							?	?
Relative strength	7-14	5	6	6	6	4	4	3	4	8	8	5,2 **b**	5,6 **7**
	15-x	5	8	-	-	4	4	8	1	-	-	5,7 **b**	4,3 **5**
MAP	7-14	3	5	6	6	2	2	4	6	5	9	4 **4**	5,6 **7**
	15-x	2	2	-	-	1	1	7	8	-	-	3,3 **3**	3,7 **3**
Balance	7-14							5	7	3	2	4 **4**	4,5 **4**
	15-x							1	3	-	-	?	?
Flexibility	7-14	9	4	8	4			1	5	10	5	7 **11**	4,5 **4**
	15-x	7	4	-	-			6	5	-	-	6,5 **8**	4,5 **6**

Only the body height and the eye-movement co-ordination show the strongest genetic control in both sexes throughout the ontogenesis, while other features differ quite significantly. With the age, the movement speed ranking is improved in boys, reaction time and relative strength in girls are improved, while the body weight factor loses its place. Generally speaking, this approach shows much smaller inter-traits differences in genetic conditioning than the analyses show, which hare provided for single populations. Having this in mind, we decided to simplify the analysis at a later stage even more, calculating the arithmetic average values for heritability indices of particular traits in both age groups referred to above, and to determine on that basis the total (for the entire material) ranking of particular traits in the genetic conditioning hierarchy (see Tab. 5). This way seems to be justified, as we are entitled (see table 3) to assume that traits of a specific genetic control are located in similar (though not identical) ranks within the hierarchy in the analysed growth period. It seems that only this approach allows for more comprehensive assessment of earlier conclusions. Actually, the genetic control strength for quantitative traits is increased with age (for 20 out of 22 cases), but only in the case of $V_{O2\,max}$, MAP and balance is it stronger in males, whereas in females it applies to fat and flexibility. The inter- trait hierarchy is very similar in both sexes: body height and eye-movement co-ordination show the strongest genetic control, with fat mass, simple reaction time and flexibility left out in the weakest position. Also, V_{O2max} and balance are ranked quite high, but these data apply only to 2 populations (1 in the adult group). Based upon the generally approved criteria (Sergienko 1999), the analysed traits may then be grouped as follows:

Table 5. Comparison of average weighted h^2 values in comparable populations (from five populations).

TRAIT	AGE	SONS		DAUGHTERS		TOTAL		GENERAL
		h^2	rank	h^2	rank	h^2	rank	
Body height	7-14	0,59	1	0,47	1	0,53	1	0,63
	15-x	0,68	1	0,74	1	0,71	1	
Body mass	7-14	0,33	8 [4]	0,41	3 [5]	0,37	5	0,38 [5]
	15-x	0,46	5	0,35	9	0,40	6	
Fat mass	7-14	0,39	4 [7]	0,38	4 [5]	0,38	4	0,30 [9]
	15-x	0,08	9	0,36	8	0,22	9	
Simple reaction time	7-14	0,35	7 [4]	0,16	11 [9]	0,25	11	0,32 [8]
	15-x	0,40	6	0,41	7	0,40	6	
Eye- move-ment co-ord	7-14	0,44	3 [2]	0,44	2 [2]	0,44	2	0,54 [2]
	15-x	0,62	2	0,63	2	0,63	2	
Movement speed	7-14	0,24	11 [4]	0,30	7 [4]	0,27	9	0,40 [3]
	15-x	0,62	2	0,44	4	0,53	3	
Relative strength	7-14	0,32	9 [8]	0,22	10 [7]	0,27	9	0,36 [6]
	15-x	0,33	7	0,58	3	0,45	5	
MAP	7-14	0,38	5 [3]	0,28	8 [8]	0,33	6	0,40 [3]
	15-x	0,58	4	0,41	6	0,48	4	
Balance	7-14	0,48	2 [?]	0,37	5 [?]	0,43	3	? [?]
	15-x	0,78	-	0,60	-	-	?	
Flexibility	7-14	0,29	10 [9]	0,35	6 [3]	0,32	7	0,37 [7]
	15-x	0,29	8	0,44	4	0,36	8	
V_{O_2}max	7-14	0,36	6 [?]	0,25	9 [?]	0,31	8	? [?]
	15-x	0,86	-	0,42	-	-	?	

a). strong genetic control:

- body height (average $h^2 = 0.62$),
- eye-movementco-ordination ($h^2 = 0.54$),
- balance (?): average $h^2 = 0.56$.

b). average genetic control:

- VO2max (?): average $h^2 = 0.48$,
- movement speed ($h^2 = 0.40$),
- MAP ($h^2 = 0.40$).

c). weak genetic control:

- body weight ($h^2 = 0.38$),
- relative strength ($h^2 = 0.36$),
- flexibility ($h^2 = 0.34$),
- reaction time ($h^2 = 0.32$),
- fat mass ($h^2 = 0.30$).

Figure 1 illustrates the described phenomena, in which the features are provided ranked according to the h^2 value in two age groups for both sexes: the tendency for stabilising the "rank" is quite significant here in both compared periods, exceptions only refer to movement speed in girls (increased) and body weight in girls (reduced). Significant inter-sex differences are characteristic only of reaction time (high rank in males).

Figure 1. Ranking of particular traits in boys and girls (according to average weighted h^2 values) in two age groups

Boys		Girls	
7-14	15-x	7-14	15-x
1. Body height	1. Body height	1. Body height	1. Body height
2. Balance	2. Eye-movement coordination	2. Eye-movement coordination	2. Eye-movement coordination
3. Eye-movement coordination	3. Movement speed	3. Body mass	3. Relative strength
4. Fat mass	4. MAP	4. Fat mass	4. Flexibility
5. MAP	5. Body mass	5. Balance	5. Movement speed
6. Vo_2max	6. Reaction time	6. Flexibility	6. MAP
7. Reaction time	7. Relative strength	7. Movement speed	7. Reaction time
8. Body mass	8. Flexibility	8. MAP	8. Fat mass
9. Relative strength	9. Fat mass	9. Vo_2max	9. Body mass
10. Flexibility		10. Relative strength	
11. Movement speed		11. Reaction time	

The results obtained are difficult to discuss, as they only may be referred to synthetic works, with the results being compared in research in many populations, and this are scarce (Kovar 1980, Wolanski and al. 1991, Bouchard and al. 1997, Sergienko 1999). It seems, however, that the results are coherent, at least for general tendencies, for mutual inter-feature relationships, as well as for trends in their changes with age.

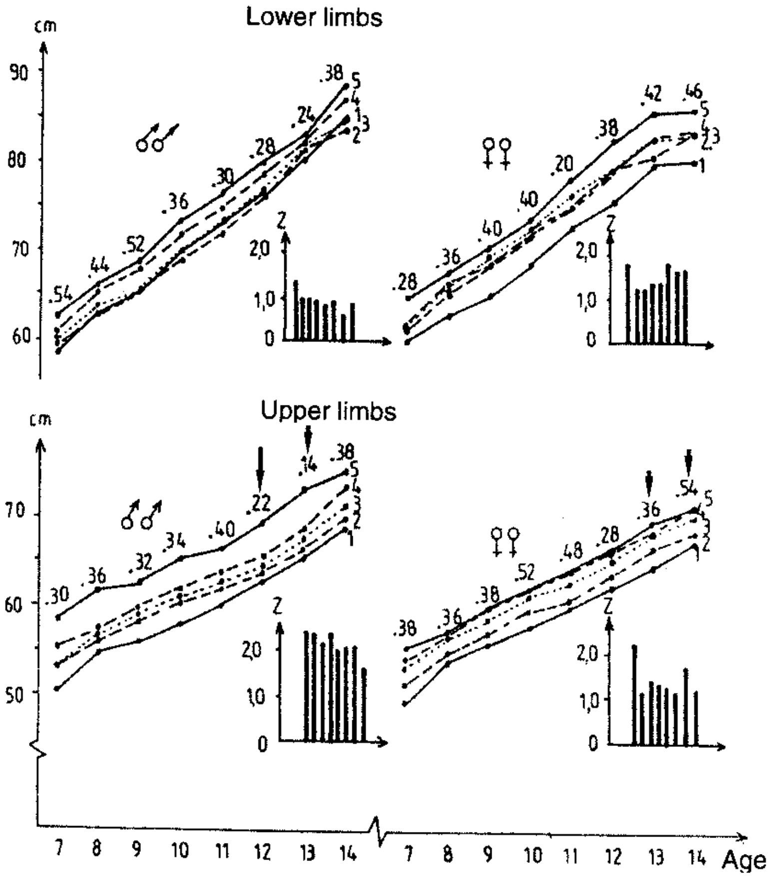

Figure 2. Variability of the limb length in boys and girls between 7 and 14 years of age in groups selected according to the mid-parent values

Explanation:

1. 0, 54, 0, 44 etc. – h^2 values
2. Z – standardised differences (Zg) between children from extreme (1–5) groups in mid-parent values groups

One conclusion is obvious, however: no general conclusions may be made as regards the genetic control strength for particular traits on the basis of research made on one population only, be it as numerous as one can imagine, **as they are limited exclusively to this very population**. It seems also that heritability indices (calculated on the basis of correlation coefficients as they are) are a relatively "weak:" measure, as they are burdened with large standard error. Thus we believe (what earlier was proposed by Bergman for the twins method: 1988) that it shall be supplemented with additional methods, which would give a broader view of the genetic factor operating. Such a method was suggested by Szopa (1990): the assessment of the amount of "genetic variation" in the trait level in children (in their growth) in specific value categories of these trait in parents (the best approach would be the "mid-parent value" as the one, which is strongest correlated with the level of the traits in children). The method consists in calculating average, **standardised** values of the given feature in **children** in groups selected according to the mid-parent values (e.g. a division into 5 groups according to 1/2 of the standard deviation: then the middle group covers the range of x_+1/4 SD, with groups of smaller and higher values in the 1/2 SD ranges). The variation run in such selected categories, especially the difference values between children from extreme groups (we have called them Z_g: the genetic variation indices) certify the actual influence of parental genotype on the course of the development of these traits in children, thus being a valuable (if not more certain) method for supplementing the values of heritability indices.

How big the differences between the two methods may be is seen from the examples presented in Szopa (1990), which illustrate the course of the body height development and the length of upper limbs in children examined longitudinally between 7 and 14 years of age; they are given in Figure 2. As one can notice, major differences are present between h^2 (in digits above the chart) and Z_g: the special high differences are marked with arrows. However, it turns out that the h^2 indices calculated for upper limbs length are much smaller than for the body height, with the genetic differentiation (Z_g) even stronger. In some cases, h^2 drops down, with Z_g rising, which confirms the thesis of high lability of the heritability index.

On the basis of the presented data one can conclude that all the preliminary theses of this paper have been positively verified:

1. High variability in family similarities (and genetic control strength) have been proved, which result from the environmental specific nature of the examined population, thus the conclusions have to be limited only to the tested material and interpretation has to be limited to relative terms (stronger – weaker), not to exact numerical data. Generalisations may only be done when the hierarchy of genetic conditioning is compared in many populations.

2. The thesis has been confirmed of relatively low diagnostic value of the heritability index, which suggests the necessity of supplementing it with complementary methods.

3. General regularities have been determined with high probability on shaping the genetic control strength for various traits (including the functional ones) in both sexes and in various periods of the ontogenesis. Out of 11 traits analysed in five populations, body height and eye-movement co-ordination (probably balance, too) showed relatively high genetic control; V_{O2max}, movement speed and maximum anaerobic power – average; and body weight, relative strength, flexibility, reaction time and fat mass: weak. The genetic factor showed increasing (though proportionally) importance with age, with inter-sex differences and the so-called "puberty wobbling" of much less importance.

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