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Relations between Morphological and Cognitive Dimensions of Persons with Above-Average Motor Abilities

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A B S T R A C T

The set of 33 anthropometric measures and the battery KOG3 to estimate the perceptive, serial and parallel processors were applied on the sample of 217 students of the Faculty of Sport and Physical Education in Novi Sad (Serbia). By means of factor analysis with the oblimin rotation, the following morphological dimensions were obtained and analyzed: 1) longitudinal skeletal dimensionality, 2) transversal skeletal dimensionality, 3) volumen and body mass, 4) subcutaneous fat and 5) head voluminosity. After the transformation of the results from linear model of the relations into the non-monotonous spline function of the forth degree, the results of correlation, canonical correlation and redundancy analyses were subjected to the non-linear model analysis. The obtained results showed that the non-linear model of data analyses indicated more significant relations and explained better the common variance of the two sets of variables.

Key words: *non-linear model, morphological characteristics, cognitive dimensions, students of sport and physical education*

Introduction

Relations of morphological and cognitive dimensions were subject of interest of just a few research works only. Far more research works were concerned with relations of morphological dimensions on one side and motor and conative dimensions on the other, predominantly in the field of kinesiology, but less in the field of psychology. The research works referred to here are those which have defined these relations within bio-orthogonal model of canonical correlation analysis or within the model of regression analysis. Results of this research indicate a relatively low but significant relation between morphological and cognitive dimensions, which is best reflected in positive relation of general cognitive factor and general growth and development in ontogenetic development of the man[1–6]. These research works indicate that there is a positive relation between cognitive functioning (general intelligence) and harmonious human growth and development. There are other studies which indicate that people expect physically attractive others to be more intelligent than physically less attractive others[7] and that beautiful people are more intelligent[8].

It can generally be concluded that practically all results of this research point to a tendency of positive relations between cognitive abilities, especially general factor, and a harmonically powerful constitution in men.

All above research works were performed according to the linear model on the subjects without any specific characteristics. However, it is known that relations of the analyzed anthropological dimensions are not independent from certain exogenous factors, and that they are predominantly determined by social, economical and cultural status of an individual, his family, as well as micro and macro environment the man lives and develops in, and the kind, frequency and intensity of the practiced kinesiological activities. The results of certain research works[9] indicate that even after partialization of the space of morphological and cognitive dimensions by dimensions of social status, the relations of such dimensions remain practically the same as in the above research works. The number of similar research works on subjects with above-average motor abilities, or those related to the mo-

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dality and intensity of occupation with kinesiological activities is much lower.

Thus the purpose of this research is to fill the gap and contribute to understanding the relationship between morphological and cognitive dimensions of persons in relatively stable phase of biological growth. To be more specific, this is the question of morphological characteristics and intellectual abilities of subjects with above-average motor abilities in comparison to their peers.

Materials and Methods

Subjects

Research sample included practically all male students of the second and third year studies at the Faculty of Sport and Physical Education in Novi Sad. Analysis included 217 subjects.

Measures and tests

The sample of 5 morphological dimensions was obtained according to the PB criterion and oblimin transformation of the principal components of anthropometrical variables, on the basis of measurements of the following anthropometrical measures: 1) body height, 2) sitting height, 3) height of spina iliaca anterior superior (leg length), 4) thigh length, 5) tibial length, 6) arm length, 7) upper arm length, 8) forearm length, 9) biacrominal breadth (shoulder width), 10) transverse chest breadth, 11) anterior-posterior chest depth, 12) biilliocristal breadth (width of pelvis), 13) head length, 14) head width, 15) bizygomatic breadth, 16) bigonion breadth, 17) morphological face height, 18) nose height, 19) nose breadth, 20) head girth, 21) humerus width (elbow width), 22) wrist width, 23) femur width (knee width), 24) bimalleolar width (ankle width), 25) chest girth, 26) midarm girth in relaxed position, 27) midarm girth in contraction, 28) calf girth, 29) body weight, 30) triceps skinfold, 31) subscapular skinfold, 32) abdominal skinfold, 33) medial calf skinfold. All measures were applied according to the International Biological Program (IBP), whereas measurements were performed by research assistants of the Institute for Biology and Ecology of the Faculty of Natural Science and Mathematics of the University of Novi Sad. Final results of the above research produced morphological factors (dimensions) whose vectors were positively oriented and interpreted as: 1) longitudinal dimensionality of skeleton, 2) transversal dimensionality of skeleton, 3) body voluminosity and mass, 4) subcutaneous fat tissue, and 5) voluminousity of head.

Cognitive dimensions were evaluated according to a cybernetic model of cognitive functioning, using the battery KOG3[10]. The KOG3 battery consists of three tests of cognitive functioning, which evaluate the efficiency of perceptive (IT1), serial (AL4), and parallel (S1) processors. Psychological testing was carried out by research assistants of University of Novi Sad: Faculty of Philosophy – Department of Psychology.

Data analysis

Test results and their relations were analyzed by transformation into non-monotonous splines of the fourth degree, followed by canonical correlation analysis as well as canonical analysis of overlapping known as redundancy analysis, within the non-linear model defined in such a way (QCCR)[11].

Results and Discussion

All results of this research were presented in a highly reduced form, including interpretation of only the most important information on the relations of morphological and cognitive factors within the non-linear model.

Analysis of common variability of morphological and cognitive variables in relation to linear and non-linear model was based on Table 1. According to the initial, i.e. linear model, common variance was $\rho^2=0.03028$ (3.03%), but after transformation into non-monotonous spline function of the fourth degree when it stabilized after the 28th iteration, it increased to 8.69%. In this manner, total space of variables was explained in much more details within the non-linear model, which might be an indicator of really significant relations between the analyzed morphological and cognitive space.

Correlations between morphological factors after transformation into spline function are given in Table 2, in which the relations are generally weaker than those resulted from the research within the linear model[12–17]. Correlations between cognitive factors after being transformed into spline function (Table 3), are also much weaker than the relations noticed within the linear model, based on the recent experience with the same cognitive factors[18,19,10].

As changes of correlative relations were noticed in each factor set after the simultaneous transformation of morphological and cognitive factors into non-monotonous spline function of the fourth degree, real expectations were that cross-correlations between them would be changed (Table 4). One can notice a significant negative correlation between voluminosity of head and subcu-

TABLE 1
HISTORY OF ITERATIVE PROCESS FOR TRANSFORMATION OF VARIABLES INTO NON-MONOTONOUS SPLINES OF THE FOURTH DEGREE

Iteration number	Average change	Maximum change	Average squared r (ρ^2)	Criterion change
1	0.26443	6.57014	0.03028	.
2	0.19187	5.11776	0.06403	0.03374
3	0.10358	1.63112	0.07822	0.01419
4	0.06434	0.71614	0.08251	0.00429
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
28	0.00001	0.00016	0.08695	0.00000

TABLE 2
CORRELATIONS AMONG THE SPLINES OF MORPHOLOGICAL FACTORS

Factors	1	2	3	4	5
1. Longitudinal dimensionality of skeleton	1.0000	0.0710	0.1067	0.0181	0.2196
2. Transversal dimensionality of skeleton	0.0710	1.0000	0.2413	0.0535	0.2640
3. Body voluminosity and mass	0.1067	0.2413	1.0000	0.3532	0.3266
4. Subcutaneous fat tissue	0.0181	0.0535	0.3532	1.0000	0.1069
5. Voluminousity of head	0.2196	0.2640	0.3266	0.1069	1.0000

TABLE 3
CORRELATIONS AMONG THE SPLINES OF COGNITIVE FACTORS

Factors	1	2	3
1. Perceptive processor	1.0000	0.1028	0.0060
2. Serial processor	0.1028	1.0000	0.1073
3. Parallel processor	0.0060	0.1073	1.0000

taneous fat, and a factor of perceptive processing. The ability of serial processing is in a significant positive correlation with the body volume and mass. The factor of parallel processing is not in a statistically significant correlation with morphological characteristics of the analyzed subjects. As it has been known so far, these results are different from those obtained in the research works mentioned earlier, which were performed on young people without above-average motor abilities. They can probably be explained by specificities of the subjects, i.e. by relative homogeneity of above-average motor abilities, which is one of the criteria for selective choice of candidates for studies of sport and physical education. These ablities have developed for several years under the effects of proper kinesiological treatments which have also taken effect on the specific growth and development of morphological characteristics, as well as on the development and level of cognitive functioning of students of sport and physical education.

TABLE 4
CROSS-CORRELATIONS AMONG THE SPLINES OF MORPHOLOGICAL AND COGNITIVE FACTORS

Factors	Perceptive processor	Serial processor	Parallel processor
Longitudinal dimensionality of skeleton	0.0790	–0.0610	–0.1045
Transversal dimensionality of skeleton	–0.0204	–0.0372	0.1257
Body voluminosity and mass	–0.0182	0.1595	–0.1036
Subcutaneous fat tissue	–0.2381	–0.1032	–0.0540
Voluminousity of head	–0.2174	–0.0317	0.0969

Results of canonical correlation analysis and redundancy analysis are presented in the following tables. Tables 5 to 7 present information which has lead to the statement that the relations of the first two pairs of canonical factors, based on non-monotonous spline function of the fourth degree, were statistically significant at the level of $p=0.01$, and that the relation of the third pair was not statistically significant, due to the fact that the analysis within a non-linear model commonly deals with the 0.01 significance only (Table 7). The relation between the first and the most important pair of canonical factors is explained by 17.10%, while the second pair is accounted for by 5.36% of the common variability (Table 5). Naturally, out of the total variance of the possible pairs, the first pair is explained by 68.65% and the second one by 18.83% (Table 6).

Definition of canonical factors in each space of the analyzed splines of the corresponding factors was performed based on the standardized canonical coefficients (V and W) and the structure of canonical factors (SV and

TABLE 5
CANONICAL CORRELATIONS OF MORPHOLOGICAL FACTORS AND COGNITIVE VARIABLES (ρ), ADJUSTED CANONICAL CORRELATION (r), STANDARD ERROR OF CANONICAL CORRELATIONS (Se) AND CANONICAL COEFFICIENTS OF DETERMINATION (ρ^2)

Rank	ρ	r	Se	ρ^2
1	0.413561	0.381238	0.056145	0.171033
2	0.231435	.	0.064101	0.053562
3	0.190383	.	0.065274	0.036246

TABLE 6
EIGENVALUES OF CANONICAL EQUATIONS (λ), DIFFERENCES OF EIGENVALUES (δ), PROPORTIONS (p), AND CUMULATIVE PROPORTIONS OF THE EXPLAINED VARIANCE (k)

Rank	λ	δ	p	k
1	0.2063	0.1497	0.6865	0.6865
2	0.0566	0.0190	0.1883	0.8749
3	0.0376	.	0.1251	1.0000

TABLE 7
TESTS OF SIGNIFICANCE OF CANONICAL CORRELATIONS: RATIO OF LIKELIHOOD (L), APPROXIMATE F VALUE (f), DEGREES OF FREEDOM (d1, d2), AND PROBABILITIES OF ERROR IN REJECTING HYPOTHESES THAT CANONICAL CORRELATIONS ARE EQUAL TO ZERO (p)

Rank	L	f	d1	d2	p
1	0.75612862	4.1411	15	582.8795	0.0001
2	0.91213337	2.4941	8	424	0.0118
3	0.96375435	2.6702	3	213	0.0485

SW) (Tables 8 and 9). The first canonical correlation amounted to 0.41 which explained about 17% of variability of the common space of the morphological and cognitive factors. This value is slightly lower than the one obtained by Momirović and Hošek (1982) with similar number of students of sport and physical education, on similar sample of morphological factors (without dimensionality of head) and cognitive factors (with a higher number of manifest cognitive variables), provided that the analysis was carried out within the linear model. It is interesting that the above authors got only one statistically significant canonical correlation, whereas the non-linear model of data analysis reveals a more complex relation between morphological and cognitive factors. Canonical correlation of the second pair of canonical factors amounted to 0.23, whose common variability may be explained by 5.3% of common variability of the remaining parts of the analyzed space of morphological and cognitive factors (Table 5).

TABLE 8
STANDARDIZED CANONICAL COEFFICIENTS (V) AND STRUCTURE OF CANONICAL FACTORS (S) FOR THE SPLINES OF MORPHOLOGICAL FACTORS

Factors	V1	V2	SV1	SV2
Longitudinal dimensionality of skeleton	–0.2971	–0.2162	–0.1919	–0.1252
Transversal dimensionality of skeleton	0.1888	–0.5922	0.2156	–0.3566
Body voluminosity and mass	–0.7402	0.7214	–0.2546	0.7365
Subcutaneous fat tissue	0.6672	0.2994	0.4877	0.5432
Voluminousity of head	0.7231	0.2306	0.5372	0.2944

TABLE 9
STANDARDIZED CANONICAL COEFFICIENTS (W) AND STRUCTURE (S) FOR THE SPLINES OF COGNITIVE FACTORS

Factors	W1	W2	SW1	SW2
Perceptive processor	–0.7540	–0.6625	–0.7977	–0.6028
Serial processor	–0.4518	0.6149	–0.4806	0.4844
Parallel processor	0.4532	–0.5821	0.4002	–0.5201

TABLE 10
CORRELATIONS OF THE CANONICAL STRUCTURE BETWEEN THE SPLINES OF MORPHOLOGICAL FACTORS AND CANONICAL FACTORS OF THE SPLINES OF COGNITIVE FACTORS (CROSS-STRUCTURE OF MORPHOLOGICAL CANONICAL FACTORS)

Factors	SW1	SW2
Longitudinal dimensionality of skeleton	–0.079	–0.029
Transversal dimensionality of skeleton	0.089	–0.082
Body voluminosity and mass	–0.105	0.170
Subcutaneous fat tissue	0.201	0.125
Voluminousity of head	0.222	0.068

Canonical factors from the space of morphological dimensions (Table 8) indicate that the first factor defines shorter persons of lower voluminosity, with greater share of subcutaneous fat tissue, strong and thick bones, and marked head dimensions. According to Conrad's typology[20], such constitution points to the presence of pyknomorphic and asthenic characteristics in students of sport and physical education, which does not fit into stereotypical views on body constitution of these students. Naturally, on the other pole of this factor, there are persons defined by greater longitudinal dimensionality of skeleton, smaller i.e. gracious transversal dimensionality of skeleton, marked body volume and mass due to muscular tissue predominantly, but also smaller head dimensionality. Such a constitution is an indicator of stenomorphism, as one of the modalities of athletic i.e. mesomorphic body-build.

According to the standardized canonical coefficients and structure of canonical factors in the space of cognitive variables (Table 9), a conclusion can be drawn that the first canonical factor is characterized by efficient parallel processing but inefficient perceptive and serial processors. Naturally, persons with a marked functioning of perceptive and serial processors but a pointedly weak parallel processor are located on the other pole of the first canonical factors.

Correlations between the first pair of canonical factors of the expressed morphological characteristics and the structure of cognitive factors (Table 10) indicate that there is a statistically significant and positive relation between head dimensionality and subcutaneous fat on one side and efficiency of parallel processing, and inefficiency of perceptive and serial processor on the other.

The second canonical morphological factor defines on one pole the persons of smaller transversal and longitudinal dimensionalities of skeleton, but marked body voluminosity and mass due to greater amount of fat tissue, and greater head voluminosity. This is obviously the question of the characteristics of pyknic body-build, as per Kretschmer's typology[21], i.e. characteristics of pyknomorphic type according to Conrad, however, in contrast to a similar structure of the first factor, here it is the question of sthenic body constitution of students. On the opposite pole of the second canonical morphological factor, there are characteristics which define persons with marked transversal and longitudinal dimensionality of skeleton, low volume and mass of body, unsteady tendency toward accumulation of subcutaneous fat tissue, as well as smaller head voluminosity. Such structure points to leptosomatic body-build, i.e. leptomorphic constitution of students.

The second canonical cognitive factor defines the persons with very good efficiency of the serial processor, but inefficient perceptive and parallel processing on one pole, and the persons with marked efficiency of perceptive and parallel processing but weak serial processing on the other.

Behavior of the variable for evaluation of perceptive processing might indicate that it probably occurs as a

suppressor in this sample, and that it is not very significant for the total cognitive processing in this case, owing to the fact that the subject sample is rather homogenous in relation to cognitive and motor dimensions. On the basis of this, it can reasonably be assumed that this sample was more homogenous in perceptive processing than in other cognitive dimensions.

Correlations between the second pair of canonical factors of the marked morphological characteristics and the structure of cognitive factors (Table 10) show that there is a statistically significant and positive relation between body voluminosity and efficiency of serial processor, as well as inefficiency of perceptive and parallel processors.

On the other hand, cognitive dimensions are significantly related with the structure of the morphological canonical factors in the following ways (Table 11).

1) Perceptive and serial processings are in statistically significant negative correlation, whereas parallel processing is in positive correlation with the body constitution which indicates the presence of pyknomorphic and asthenic characteristics. Thus it is the question of shorter persons of lesser voluminosity but with greater share of subcutaneous fat tissue, strong and thicker bones, and marked head voluminosity. By this analogy, persons with stenomorphic athletic built, i.e. persons defined by greater longitudinal dimensionality of skeleton, gracious transversal dimensionality of skeleton, marked body volume and mass mostly due to muscular tissue, and smaller head voluminosity, show better abilities of perceptive and serial processing but weaker parallel processing.

2) The ability of perceptive processing is in negative correlation with the characteristics of pyknic body-build type, which is related to the sthenic body composition, i.e. persons with lesser longitudinal and transversal dimensionality of skeleton, marked body voluminosity and mass due to greater amount of fat tissue, as well as greater head voluminosity. However, a positive correlation of perceptive processing may be attributed to the characteristics of leptosomatic body-build, or those which define persons of marked longitudinal and transversal dimensionality of skeleton, small body volume and mass, very small amount of subcutaneous fat tissue, as well as small head voluminosity.

TABLE 11
CORRELATIONS OF THE CANONICAL STRUCTURE BETWEEN THE SPLINES OF COGNITIVE FACTORS AND CANONICAL FACTORS OF THE SPLINES OF MORPHOLOGICAL FACTORS (CROSS–STRUCTURE OF COGNITIVE CANONICAL FACTORS)

Factors	SV1	SV2
Perceptive processor	–0.3299	–0.1395
Serial processor	–0.1988	0.1121
Parallel processor	0.1655	–0.1204

3) Marked ability of serial and parallel processing is noticed in persons of a frequent modality of athletic type, characterized by lower height, absence of fat tissue, but greater body volume and mass due to greater share of muscular tissue and thicker bones, as well as greater head voluminosity. On the other pole of this relation, there are characteristics of persons with lower efficiency of serial and parallel processors, with leptomorphic modality of sthenic body-build assuming greater longitudinal and smaller transversal dimensionality of skeleton, smaller volume and mass of the body due to greater share of subcutaneous fat tissue, and smaller head voluminosity.

4) Analyzing the relations and their structures of pairs of canonic factors within the non-linear model, it may be noticed that the persons with sthenic body constitution (reflected by body size rather than its constitution) had predominantly better cognitive functioning i.e. the ability to solve complex problems, especially with effective use of parallel processor. Due to the specificity of the subject sample in this research, this general conclusion should definitely be rechecked on other subjects of the same sex and similar age without marked kinesiological activities. This is very important, as a public

TABLE 12
RESULTS OF CANONICAL REDUNDANCY ANALYSIS

Proportions of standardized variance of the morphological factors explained by:					
	Their own canonical factors			Cognitive canonical factors	
Rank	Proportion	Cumulative proportion	Canonical R–Squared	Proportion	Cumulative proportion
1	0.1349	0.1349	0.1710	0.0231	0.0231
2	0.2134	0.3483	0.0536	0.0114	0.0345
3	0.1683	0.5166	0.0362	0.0061	0.0406
Proportions of standardized variance of the cognitive factors explained by:					
	Their own canonical factors			Morphological canonical factors	
Rank	Proportion	Cumulative proportion	Canonical R-Squared	Proportion	Cumulative proportion
1	0.3425	0.3425	0.1710	0.0586	0.0586
2	0.2895	0.6320	0.0536	0.0155	0.0741
3	0.3680	1.0000	0.0362	0.0133	0.0874

confirmation of such results would raise social significance of kinesiological treatments aimed at improvement of morphological status, as well as cognitive functioning of children, youth and adults, to a certain extent.

Based on the standardized variance of morphological factors engaged in the common variance of each pair of canonic factors from morphological and cognitive space, it may be observed that cognitive factors explain this relation better than the proportions of the share of morphological factors (Table 12).

According to this finding, a real assumption can be made that the actual form of relations between morphological and cognitive factors is not symmetric. This finding may be due to specific characteristics of this subject sample, and it can also be the consequence of e selection based on orientation of sport-active young people to study at faculties of sport and physical education, as well as the selection at entrance examinations.

It is not possible to give a full explanation of the obtained relations. Results of non-linear analysis are probably more trustworthy than the ones obtained by linear analysis. The same holds true of the belief that this is the question of non-symmetrical relations, but it is still unrewarding to explain generators of such relations. Effects of endogenous and exogenous factors, i.e. the role of genotype and phenotype in creating para-variations and modifications in relation to the body composition and the central nervous system during ontogenesis and in several human generations is not fully clear.

According to evolutionary psychologists, the human brain, just like the whole body, is adapted, not only to the current environment, but also to the ancestral environment in which we evolved[8]. Due to this, interpretations of results of this research are reduced to descriptive level of the observed structure of relations.

Conclusion

According to the obtained results in this research the following general conclusions can be drawn:

- Non-linear model shows more significant relations and it also provides better explanation of common variability of the analyzed morphological and cognitive factors transformed into the spline function;
- Analysis of relations of pairs of canonical factors and their structure within the non-linear model indicate that persons with sthenic body-build had generally better cognitive functioning;
- The obtained relations are not symmetrical since cognitive functioning enabled better prediction of the morphological status than the prediction of cognitive functioning based on the morphological status of subjects;
- The obtained results should be checked on entities from the standard population, i.e. on the young people who were not subjected to different treatments of rather intensive and frequent kinesiological activities, in order to determine whether the obtained results are specific for the analyzed subject sample or they can be generalized for other persons of the same sex and age.

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RELACIJE MORFOLOŠKIH I KOGNITIVNIH DIMENZIJA KOD OSOBA IZNADPROSEČNIH MOTORIČKIH SPOSOBNOSTI

S A Ž E T A K

Na uzorku od 217 studenata Fakulteta fizičke kulture u Novom Sadu izmjerene su 33 antropometrijske mjere prema Internacionalnom biološkom programu i bila je primjenjena baterija KOG3 za procjenu perceptivnog, serijalnog i paralelnog procesora. Analiza je obuhvatila slijedeće morfološke dimenzije, koje su dobijene rotacijom značajnih glavnih komponenata antropometrijskih varijabli: 1) longitudinalna dimenzionalnost skeleta, 2) transverzalna dimenzionalnost skeleta, 3) volumen i masa tijela, 4) potkožno masno tkivo i 5) voluminoznost glave. Nakon transformacije manifestnih varijabli u nemonotone splajnove četvrtog reda, rezultati su analizirani kanoničkom korelacijskom analizom. Analizirajući strukture relacija značajnih parova kanoničkih faktora pod nelinearnim modelom, uočava se da su osobe sa steničnom građom tijela imale, uglavnom, bolje kognitivno funkcioniranje. Dobijene relacije nisu bile simetrične, budući da se kognitivnim funkcioniranjem mogla izvršiti bolja predikcija morfoloških dimenzija, nego efikasnost kognitivnog funkcioniranja na osnovu morfoloških dimenzija ispitanika.