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The Mechanisms of Morphological-Motor Functioning in Elementary School Female First- to Fourth-Graders

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A B S T R A C T

Four morphological and 7 motor variables were assessed in a sample of 2,235 female children (subdivided into 4 groups) aged 7–11 years, elementary school first- to fourth-graders from the Primorje-Gorski Kotar County, Republic of Croatia. The study objective was to analyze the morphological-motor structures according to age. Factor analysis was done for each of the four subject groups. Results clearly showed the morphological-motor functioning of the girls to change with age. Developmental processes lead to the formation of a general morphological factor defined as ectomesomorph and two general mechanisms responsible for motor efficiency in the form of strength regulation and speed regulation. The results obtained were found to be consistent with the existing relevant models related to the morphological, motor, functional and cognitive systems. The more so, these results allow for a supramodel to design, which will integrate relevant elements of all these models to define the function of the body as a whole.

Key words: *morphological-motor structures, girls, development, regulatory mechanisms*

Introduction

The majority of studies investigating the structure of morphological characteristics included stable samples, i.e. subjects with little chance for any substantial result oscillations. Relatively reliable indicators of the final morphological structure and dimension relations that can be considered final or permanent

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have thus been obtained[1,2]. These results show that four morphological dimensions can generally be identified in adult individuals. A three-dimensional model is found in adolescents[3], whereas two morphological dimensions have generally been identified in children[4].

The general developmental tendencies reflect upon all other body subsystems, which are inter-related and require multisegment and multidisciplinary approach whenever possible[4–9].

Previous studies of motor abilities, which employed the functional approach, have enabled a cybernetic model of motor functioning in man to design. In these studies, the model is functionally defined by physiologic mechanisms which, according to Bernstein's (1966)[10] and Anohin's (1970)[11] theories of afference and re-afference processes, act at different levels of the nervous system and are included in the regulatory circuits of a higher or lower order, depending on the motor task content[3,12].

The model of motor functioning is based on the idea of identification of the functional mechanisms that are latently contained in the complex pattern of the central nervous system functioning and underlie motor reactions. This concept relies on the hypothesis which has been confirmed on several occasions, that the output motor manifestations are directly conditioned by efficient functioning of particular cortical and subcortical areas of the central nervous system, including the reflex arc area, and by efficient coordination of variedly located and different functional mechanisms. The internal regulatory circuit has thereby been attributed responsibility for the regulation of excitatory processes, i.e. muscle strength intensity and duration, and fine regulation of the activated musculature tone. According to this hypothesis, the external regulatory circuit is responsible for the regulation and control of complex movement structures, which generally imply coordination issues. Topologically, the internal regulatory circuit includes subcortical segments of the central nervous system, thus it is a circuit starting at the lowest level in spinal zone and ending in the zone of reticular formation. The external regulatory circuit includes all relevant mechanisms of the internal circuit, also extending and pronouncing the role of cortically located mechanisms. This is so because the formation of the complex structures of movement, which frequently imply a problem, and efficient exploiting of feedback information that are simultaneously received from a number of receptors, require functioning of the highest structures for the receipt, analysis and storage of information.

In line with this theoretical concept on the functional structure of the motor area, which has been substantiated by clinical experiments of Luria (1966, 1973)[13,14] and many others, the empirical studies of Kurelić et al. (1975)[3] have pointed to the possible existence of four functional mechanisms defining the general mechanism of energy regulation and general mechanism of movement regulation in a higher order area.

Studies have shown the motor area to be multidimensional, with the existence of primary, secondary and tertiary factors in adults[12].

As indicated by the study of Kurelić et al. (1975)[3], two latent dimensions of a broad range of regulation (the mechanisms of movement regulation and of energy regulation) are found in adolescents.

Some studies of the structure of motor abilities in children showed at least two motor dimensions to exist in the motor area in children[4,15,16]. This is so because at the age of 6–8 years, the majority of neural structures approach the adult stage and basic motor abilities have been well developed, thus ensuring prerequisites for latent motor dimension differentiation[17].

A valid and reliable assessment of the morphological-motor status is of utmost importance for the planning and programming of transformation processes in both kinesiologic education at school and various sports activities of the children and adolescents. The kinesiologic practice should imply optimal individualized evaluation using the least possible number of variables, thereby avoiding significant reduction in the amount of relevant information. Therefore, the variables that are most relevant for evaluation of the basic morphological characteristics and motor abilities, at the same time assessing a coexisting model of the morphological or motor status, should be chosen[3,12].

In the present study, the choice of morphological and motor variables was made using the morphological and motor model developed by Kurelić et al. (1975)[3] based on large samples of the school children population. The same set of variables proposed by these authors on the basis of their study results has been used on the follow up and evaluation of the morphological, motor and functional characteristics in elementary school children in the Republic of Croatia[18]. The morphological set of measures is used to evaluate the components of ectomorphy, mesomorphy and endomorphy. The set of motor tests is used to evaluate some basic motor abilities considered to be most important for the children's motor status assessment. In this way, motor status is defined by two components, i.e. energy component (action factors of strength and endurance) and information component (coordination, speed and flexibility). The existence of the general morphological factor and general motor factors will be evaluated in elementary school female first- to fourth-graders.

Methods

Study sample included 2235 female first- to fourth-graders aged 7–11 years, from elementary schools in the Primorje-Gorski Kotar County, Republic of Croatia. The sample was divided into four subgroups as follows: first-graders (n=575), second-graders (n=543), third-graders (n=573) and fourth-graders (n=544). All study children were free from visible aberrations and capable of performing the standard elementary school program.

A standard battery of 11 variables currently used in the educational system of the Republic of Croatia were employed to assess the morphological, motor and functional status of the children.

The battery of variables was suggested on the basis of a large study carried out by Kurelić et al. in 1975[3]. The morphological variables included body height (mm), body weight (dkg), forearm circumference (mm) and triceps skinfold (1/10 mm). The measures were taken according to the international biological program.

The motor variables included hand tapping (f), standing jump (cm), polygon backward (s), sit-ups (f), forward bow (cm), bent arm hang (s) and 3-minute run (m).

On data analysis, elementary statistical parameters and standard factor analysis were used. The basic variable parameters (mean and standard deviation), varimax factor, characteristic factor values (lambda) and percentage of common variance according to subgroups are presented in tables. Pooled results from four factorial analyses are shown.

Although the study was carried out in transverse samples, the results could also be interpreted through parameter changes as a function of time, because the samples were representative for the respective population and included a large number of subjects.

Results

The basic parameters of morphological measures and motor tests are presented in Table 1. Of morphological measures, body height showed a steady and continuous increase from first to third grade. The increase was more pronounced between second and third grade (about 6 cm), whereas between third and fourth grade the increase in body height was not so intensive anymore, probably due to the body preparation for the precipitate growth in puberty. The increase in body mass and volume paralleled the increase in body height, whereas adipose tissue showed a decrease in second grade followed by slight increase in third and fourth grades. Concerning motor abilities, psychomotor speed and aerobic endurance showed steady and continuous development from first to fourth grade, whereas development of coordination, flexibility and all strength factors occurred from first to third grade. In fourth grade, considerable stagnation in the development of coordination, repetitive and static strength, or even reduction of flexibility and explosive strength was recorded (Figure 1). On the one hand, this pointed to stabilization of the morphological and motor development, however, it is quite probable that physical activity practiced by the girls was inadequate to provide an adequate support to their growth and development.

Factorial analysis of the mentioned set of variables most frequently isolated three factors that explained the ever rising percentage of common variance, with the exception of third-graders in whom two varimax factors were isolated, the first one obviously indicating a more pronounced integration of motor abilities into the morphological system (Tables 2 and 3). The first varimax factor generally defined morphological structure with body mass predominance, the second varimax factor mostly defined energy regulation, and the third varimax factor defined movement structure regulation in terms of movement frequency and flexibility (except for third-graders).

Of the morphological measures used, the variables of body weight and forearm

TABLE 1
STATISTICAL PARAMETERS OF MORPHOLOGICAL AND MOTOR VARIABLES FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE GIRLS

Variable	1 (N=575)	2 (N=543)	3 (N=573)	4 (N=544)
	X±SD	X±SD	X±SD	X±SD
Stature (cm)	127.16±5.49	132.57±6.41	138.46±8.46	140.68±8.95
Body mass (kg)	26.80±5.13	29.72±6.44	33.97±7.37	35.68±7.73
Forearm circumference (cm)	18.48±1.56	18.92±1.92	19.61±2.04	19.93±2.21
Triceps skinfold (mm)	11.22±4.00	10.83±3.43	11.46±4.79	11.82±4.45
Hand tapping (taps/min)	17.85±3.31	20.40±3.98	22.66±3.97	25.04±3.71
Standing jump (cm)	108.62±17.8	118.97±19.2	131.08±20.5	130.67±20.9
Polygon backward (s)	27.00±7.92	22.45±6.27	20.45±6.55	20.23±6.75
Sit-ups (*per* minute)	23.67±7.15	26.43±7.82	28.25±7.73	28.84±7.09
Forward bow (cm)	37.84±8.35	43.63±8.73	48.14±9.81	47.06±10.7
Bent arm hang (s)	11.26±9.32	14.60±12.4	18.95±17.2	19.60±17.2
3-min run (m)	445.53±72.1	473.54±85.3	508.13±88.1	525.45±81.7

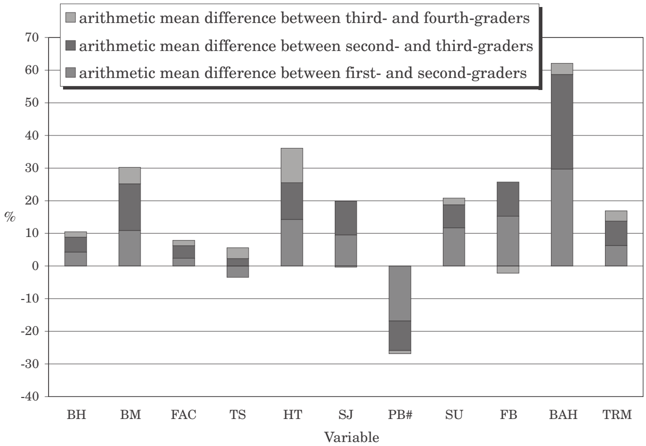

Fig. 1. Between grade arithmetic mean increase. BH = body height, BM = body mass, FAC = forearm circumference, TS = triceps skinfold, HT = hand tapping, SJ = standing jump, PB = polygon backward, SU = sit-ups, FB = forward bow, BAH = bent arm hang, TRM = three-min run, # = variable with the opposite metric orientation.

circumference exerted highest projections on the first varimax factors in first-graders, followed by the variables used for assessment of adipose tissue and longitudinal skeleton dimensions. These findings indicated the body mass to be saturated by endomorphy rather than ectomorphy, along with mesomorphy, in this subgroup. In second- and third-graders, the first varimax factor showed total body mass to be mainly saturated by mesomorphy and ectomorphy, and only to a lesser extent by endomorphy. In fourth-graders, the first varimax factor responsible for the general morphological development was predominantly and evenly defined by the variables of body weight, body height and forearm circumference, but not significantly by triceps skinfold. So, the overall morphological development from first – to fourth-grade was found to be ever more defined by mesoectomorphy, with pronounced endomorphy representing the unfavorable aspect of the body development as a whole.

In first-graders, the second varimax factor defined energy movement regulation with a predominance of explosive and repetitive strength, and aerobic endurance, accompanied by coordination and muscle endurance. The third varimax factor was defined by movement frequency and flexibility.

In second-graders, in addition to morphological factor, two motor factors of a broad range of regulation were formed, i.e. the factors responsible for energy regulation and for regulation of movement structuring in terms of movement frequency, flexibility and coordination.

In third-graders, a general motor factor was isolated in addition to the predominance of energy movement regulation. In these girls, the abilities of strength, speed and endurance were found to be integrated in the general motor ability. The variable of coordination assessment exerted a significant negative projection on the first varimax factor defining general morphological development. The performance of complex motor tasks obviously requires such a morphological complex in which all somatotype components, especially endomorphy, are under average (e.g., in women's competitive gymnastics).

TABLE 2
VARIMAX FACTORS (V) OF MORPHOLOGICAL-MOTOR AREA VARIABLES IN FIRST AND SECOND GRADE GIRLS

Variable	1 (N=575)			2 (N=543)		
	V1	V2	V3	V1	V2	V3
Stature (cm)	0.63	–0.04	0.43	0.75	–0.10	–0.12
Body mass (kg)	0.90	–0.13	0.16	0.92	0.13	0.01
Forearm circumference (cm)	0.87	0.01	0.06	0.84	0.08	0.07
Triceps skinfold (mm)	0.75	–0.07	–0.20	0.67	0.25	0.05
Hand tapping (taps/min)	–0.05	0.01	0.73	–0.04	0.07	–0.75
Standing jump (cm)	–0.09	0.68	0.26	–0.16	–0.68	–0.19
Polygon backward (s)	0.26	–0.55	–0.28	0.33	0.29	0.51
Sit–ups (*per* minute)	0.08	0.67	0.03	0.08	–0.67	–0.21
Forward bow (cm)	0.12	0.15	0.51	0.18	–0.17	–0.58
Bent arm hang (s)	–0.37	0.40	0.24	–0.27	–0.68	–0.14
3–min run (m)	–0.02	0.63	–0.25	–0.02	–0.74	0.23
Lambda	2.77	1.81	1.32	2.80	2.14	1.34
Variance (%)	25.17	16.47	12.00	25.48	19.49	12.14

TABLE 3
VARIMAX FACTORS (V) OF MORPHOLOGICAL-MOTOR AREA VARIABLES IN THIRD AND FOURTH GRADE GIRLS

Variable	3 (N=573)		4 (N=544)		
	V1	V2	V1	V2	V3
Stature (cm)	0.71	0.33	0.85	0.15	0.11
Body mass (kg)	0.91	–0.05	0.86	–0.26	–0.04
Forearm circumference (cm)	0.86	0.05	0.84	–0.24	0.04
Triceps skinfold (mm)	0.64	–0.19	0.32	–0.65	0.21
Hand tapping (taps/min)	0.10	0.57	0.13	–0.03	0.68
Standing jump (cm)	–0.18	0.75	0.17	0.78	0.16
Polygon backward (s)	0.50	–0.29	0.32	–0.62	–0.01
Sit–ups (*per* minute)	–0.14	0.60	0.07	0.34	0.62
Forward bow (cm)	0.14	0.41	0.03	–0.07	0.65
Bent arm hang (s)	–0.41	0.52	–0.08	0.67	0.22
3–min run (m)	–0.10	0.63	–0.27	0.28	0.49
Lambda	3.00	2.33	2.49	2.21	1.64
Variance (%)	27.27	21.21	22.64	20.09	14.81

The process of integration recorded in third-graders was followed by differentiation of the developmental functions of the morphological-motor system, thus upgrading its overall functioning in fourth- graders. The formation of two factors of management, i.e. for the generation of power-strength and of movement speed-frequency, was recorded. Evidently, the 11-year-old girls entered the stage of development at which the morphological-motor system elements reached optimal inter-relations and a higher, relatively stable level. This stage implied preparation for the precipitate pubertal development of all relevant body functions, which was to follow soon.

Discussion

Analysis of the children's current and developing morphological and motor status requires appropriate monitoring of not only quantitative but also qualitative changes in defined relevant parameters of the morphological-motor area, i.e. identification and comparison of the morphological-motor structure at a particular age. In the present study, the classic factorial analysis was used to identify the girls' morphological-motor structures. In this way, the mechanisms responsible for the morphologic-motor functioning at a particular age, from first– to fourth-graders, were identified.

A set of only four morphological variables proved adequate to provide relevant information on the characteristics of the morphological status development in girls aged 7 to 11 years. To put it simply, the developmental processes tend to establish optimal relationships among all elements, somatotype components. These relationships will primarily determine motor efficiency due to the interactive connections between the morphological and motor systems.

The chosen set of motor variables properly defined the motor status of the girls aged 7–11 years. The motor variable projections on isolated factors pointed to the following conclusions:

During motor development, the formation of two mechanisms responsible for motor efficiency, i.e. the mechanisms of energy regulation and of movement structuring manifestation, prevails. The former is mainly responsible for the energy component, and the latter for the information component of movement. Study results confirmed existence of the model of motor functioning proposed by Kurelić et al. (1975)[3]. As the performance of any movement and/or movement structure clearly depends on both the energy and information components, the existence of a central mechanism integrating the functions of both subordinated mechanisms has been postulated.

Isolated motor factors can be defined according to the level of the central nervous system management, whereby cortical level is involved in complex structures and subcortical level in simple structures. By analogy, complex and simple structures imply parallel and serial information processing, respectively. The mechanisms of strength and speed regulation are located at a lower level. Strength regulation is associated with parallel information processing, such as motor test performance (e.g., standing jump, bent arm hang and polygon backward), whereas speed regulation is associated with serial information processing, such as hand tapping, sit-ups (where the result depends on movement frequency rather than strength) and 3-minute run, as evident in the subgroup of 11-year-old girls. Each movement integrates strength and speed, whereas the strength to speed relations are regulated by the superior mechanism for the movement to be efficient. Study results confirmed existence of the model proposed by Gredelj et al. (1975)[12] and are consistent with the concept of a cognitive functioning model postulated by Momirović et al. (1982)[19].

Strength regulator and speed regulator are the main elements of the functional model that also implies endurance regulator[20]. The regulator of strength is associated with muscle endurance, and the regulator of speed with aerobic endurance. The terms strength endurance and speed endurance have otherwise been used in sports terminology. Results of the present study clearly depicted the functional model to completely exist in 11-year-old girls.

Kinesiologic activities are complex and their motor efficiency depends on all basic and functional abilities that should be in optimal inter-relationship. This is accomplished by the regulators located at lower and higher levels of management, with the high level regulators coordinating the work of the lower level regulators. Motor learning influences motor functioning to switch from the predominantly cortical to the predominantly subcortical level[21]. Thus, programs in the form of biomotor structures are being formed, and the learned motor structures are automatically performed, whereby the choice of reaction, i.e. the mode of implementing the adopted motor programs in a particular situation, occurs at the cortical level.

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MEHANIZMI MORFOLOŠKO-MOTORIČKOG FUNKCIONIRANJA KOD UČENICA 1.–4. RAZREDA OSNOVNE ŠKOLE

S A Ž E T A K

Na ukupnom uzorku od 2235 djece ženskog spola (sastavljenog od 4 poduzorka), polaznica prvog do četvrtog razreda osnovnih škola Primorsko-goranske Županije R. Hrvatske, starosne dobi 7–11 godina, primijenjene su 4 morfološke i 7 motoričkih varijabli. Svrha rada bila je analiza morfološko-motoričkih struktura u odnosu na starosnu dob učenica. U tom smislu na svakom poduzorku ispitanika primijenjena je faktorska analiza. Rezultati su jasno pokazali kako se ovisno o starosnoj dobi mijenja i morfološko-motoričko funkcioniranje djevojčica. Razvojni procesi dovode do formiranja generalnog morfološkog faktora definiranog kao ektomezomorfija i dva generalna mehanizma odgovorna za motoričku efikasnost i to u vidu regulacije sile i u vidu regulacije brzine. Zaključeno je da su dobiveni rezultati u skladu sa postojećim relevantnim modelima vezanih za morfološki, motorički, funkcionalni i kognitivni sustav. Štoviše rezultati omogućuju formiranje nadmodela koji integrira relevantne elemente svih navedenih modela u cilju definiranja funkcija organizma kao cjeline.