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Original scientific paper

Integration of Aerobic Power into the Morphological-Motor System in Children Aged 7–11 Years

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A B S T R A C T

The aim of the study was to analyze integration of aerobic power into other dimensions evaluated. For this purpose, predictor relations of the morphological-motor variables were analyzed with a 3-minute run as a criterion (according to school grade and sex). Four morphological and 6 motor variables covering the morphological-motor system were used in a sample of 4,440 children of both sexes aged 7–11 years, elementary school first- to four-graders from the Primorje–Gorski Kotar County, Republic of Croatia, divided into 8 groups. Data were processed by use of regression analysis. Study results clearly showed the values of the criterion variable to rise and criterion prediction using the set of predictor variables to improve with age. Also, the number of predictors included in power run prediction was observed to significantly increase with age. Strength factors with a predominance of explosive strength and repetitive strength in boys and girls, respectively, were the best criterion predictors. It is emphasized that development of the morphological-motor system and thus functioning of the body as a whole are influenced by aerobic power upgrading. Appropriate systematic kinesiologic activities accelerate the process of aerobic power integration in the morphological-motor system. As indicated by study results, this integration occurred at a faster rate and was more intensive in girls than in boys.

***Key words**: children, morphological-motor status, aerobic power, relations*

Introduction

The theory of integrated development points out that all human abilities and characteristics in the process of development are inter-related. This has been

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scientifically demonstrated, especially in the studies of relations among particular dimensions of the psychosomatic status[1].

The knowledge of developmental patterns is necessary for efficient activities aimed at quality support to the development of the child's biopsychological abilities, because there are extremely great possibilities and modes of influencing the youngest children's health and abilities[2–4]. However, the variation possibly occurring during the development of these abilities is very high as well. Therefore, systematic and controlled activities leaving minimal space for stochastic and accidental actions are of paramount importance[5–7]. School age, when the child is exposed to systematic kinesiologic treatment for the first time, is one of the crucial periods in the general development to achieve comprehensive developmental maximum. The role of the school as an institution is to provide through appropriate general and differential programs of kinesiologic education, active support to the development of the morphological-motor and functional complexes as an integral segment of the child's body as a whole, which will determine the level of development of each individual for his/her entire life as well as their integration in the psychosocial system.

Although there is a complex kinesiologic interplay of numerous simultaneous and inter-related abilities, some abilities simply have the role of a basis upon which a well-balanced development of the body relies. One of these basic abilities is aerobic power, in other words, the ability to endure a prolonged activity of submaximal intensity. The physiological background of aerobic power is well known and is predominantly determined by the quality of the system of oxygen and energy source transport and metabolite extraction. It is also known that profound changes in the system functioning should be expected just proportionally to the duration of a systematic transformation process, which can elevate transport functions to a new, higher level[8,9].

In comparison with standard education, a specially programmed kinesiologic education is considerably more efficient in the development of almost all relevant motor abilities, especially aerobic power, all strength factors and flexibility (Katić[10], Babin et al[2].). Accordingly, increased aerobic power is a major goal of every training process, as it is the basis of development and higher achievements of all other abilities, and motor abilities in particular. However, appropriate support to the child's overall anthropologic development can only be ensured by a significantly higher frequency of systematic physical activity than the one currently practiced in the Croatian elementary schools. Consequently, development per se, i.e. the continuity of developmental functions, will have a major impact on the general development of the body as a whole.

The aim of the present study was to assess the effects of standard kinesiologic education, and of the growth and development on the mutual determination of aerobic power, morphological properties and motor abilities in children, elementary school first- to fourth-graders of both sexes[11]. The study was so designed as to analyze changes in the structure of aerobic power integration in the morphological-motor system according to age (7–11 years).

Subjects and Methods

Study sample included 4,440 children of both sexes aged 7–11 years, elementary school first- to four-graders from the Primorje-Gorski Kotar County, Republic of Croatia, divided into 8 groups as follows: first-grade (n=566), second-grade (n=560), third-grade (n=561) and fourth-grade (n=518) boys, and first-grade (n=

575), second-grade (n=543), third-grade (n=573) and fourth-grade (n=544) girls. All study children were free from visible aberrations and capable of performing 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 morphological variables included stature (mm), body mass (kg), forearm circumference (mm) and triceps skinfold (1/10 mm). The measures were taken according to the international biological program[12]. The motor variables included hand tapping (taps/min), standing jump (cm), polygon backward (s), sit-ups (per min), forward bow (cm) and bent arm hang (s). Three-minute run (m) was used to assess the aerobic work value.

On data analysis, metric characteristics, basic statistical parameters and multivariate methods were used. Data related to standard linear regression analysis using the least square model were employed. Morphological and motor variables were considered as predictors, whereas 3-min run was a criterion variable.

The basic variable parameters (Mean± SD), correlation of each predictor variable with the criterion, partial regression coefficients (β), coefficient of the predictor correlation with the criterion, i.e. multiple correlation (ρ) and significance of regression coefficients and multiple correlation according to groups are presented in tables. Pooled results of eight regression 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, primarily 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 listed in Tables 1 and 2 for boys and girls, respectively. Of morphological measures, body height showed a steady and continuous

TABLE 1
STATISTICAL PARAMETERS OF MORPHOLOGIC AND MOTOR VARIABLES FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE BOYS (X±SD)

Variable	1 (N=566)	2 (N=560)	3 (N=561)	4 (N=518)
	X±SD	X±SD	X±SD	X±SD
Stature (cm)	128.82±6.36	133.51±6.47	139.72±6.21	144.38±8.99
Body mass (kg)	27.94±5.24	31.30±6.45	35.53±7.50	38.82±8.16
Forearm circumference (cm)	19.01±1.75	19.48±1.96	20.24±1.95	20.77±2.50
Triceps skinfold (mm)	10.30±3.92	9.78±3.59	10.36±4.57	10.60±3.91
Hand tapping (taps/min)	17.89±3.40	21.45±3.85	22.92±4.53	24.78±3.94
Standing jump (cm)	118.50±20.9	130.65±20.6	142.50±21.4	151.55±23.1
Polygon backward (s)#	22.73±6.25	20.05±6.40	18.27±6.41	17.86±4.81
Sit-ups (per minute)	22.83±6.38	29.10±7.50	31.04±8.11	33.12±7.69
Forward bow (cm)	36.69±8.41	39.46±8.29	44.64±11.6	44.91±11.4
Bent arm hang (s)	16.70±16.7	21.01±14.0	26.33±21.3	28.95±20.2
3-min run (m)	467.29±79.8	507.34±78.9	545.99±92.2	583.79±105

– variable with the opposite metric orientation

TABLE 2
STATISTICAL PARAMETERS OF MORPHOLOGIC AND MOTOR VARIABLES FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE GIRLS (X±SD)

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

– variable with the opposite metric orientation

TABLE 3
CORRELATION BETWEEN MORPHOLOGIC-MOTOR SPACE AND 3-MIN RUN VARIABLES FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE BOYS AND GIRLS

Variable	Boys (N=2205)				Girls (N=2235)			
	1	2	3	4	1	2	3	4
Stature	–0.09	0.08	–0.02	0.16	–0.10	–0.02	0.09	–0.12
Body mass	–0.20	–0.20	–0.27	–0.09	–0.14	–0.18	–0.16	–0.22
Forearm circ.	–0.15	–0.10	–0.17	–0.05	–0.08	–0.11	–0.12	–0.19
Triceps skinfol.	–0.14	–0.11	–0.20	–0.10	–0.04	–0.08	–0.08	–0.15
Hand tapping	0.10	0.08	0.22	0.18	0.03	0.00	0.28	0.08
Standing jump	0.23	0.28	0.26	0.45	0.18	0.29	0.37	0.24
Polygon back.#	–0.17	–0.10	–0.25	–0.23	–0.18	–0.09	–0.10	–0.18
Sit-ups	0.27	0.32	0.21	0.36	0.18	0.36	0.26	0.32
Forward bow	0.11	0.01	0.00	0.09	0.05	0.01	0.12	0.13
Bent arm hang	0.18	0.31	0.26	0.32	0.15	0.35	0.32	0.24

– variable with the opposite metric orientation

increase from first to fourth grade in boys, and from first to third grade in girls. The increase was slightly more pronounced between second and third grade, when it was about 6 cm in both sexes. In girls, the increase in body height was not intensive between third and fourth grade anymore, probably due to preparation of the body for the more intensive growth in puberty. The increase in body mass and volume paralleled the increase in body height and was to a lesser extent accompanied by an increase in adipose tissue.

In boys, a steady and continuous development of all strength factors and aerobic power was recorded from first to fourth grade, whereas a more intensive development of coordination and flexibility occurred from first to third grade. In girls, psychomotor speed and aerobic power showed steady and continuous development from first to fourth grade, whereas development of coordination, flexibility and all strength factors took place from first to third grade. In fourth grade, girls showed noticeable stagnation in the development of coordination, repetitive and static strength, or even reduction of flexibility and explosive strength. On the one hand, this means that the morphologic and motor development proceeds at a faster rate to stabilize earlier in girls than in boys, whereas on the other hand, it is quite probable that physical activity practiced by children, and especially by girls, was inadequate to support their growth and development. It is well known that girls continuously exhibit quite pronounced movement insufficiency, whereas boys frequently compensate for the lack of systematic quality activities by spontaneous and stochastic actions, which generally are more available to boys who also are faced with fewer restrictions than girls.

Correlations of morphological and motor variables with aerobic power according to the groups of boys and girls are presented in Table 3.

Most of the correlation coefficients were statistically significant, pointing to a considerable interactive association between aerobic power and morphological-motor characteristics. The studies investigating changes induced by kinesiologic treatments[10,13,14] have shown the development of aerobic power as a functional ability of the body to be the basis for the development of all other abilities including motor ones, and even of some characteristics such as morphological properties. The ability of endurance run is considerably saturated by basic motor abilities as well as by morphological characteristics. In both sexes, the latent structure of aerobic power primarily implies all strength factors (repetitive, static and explosive strength), then the abilities of coordination, psychomotor speed and flexibility. The morphological factors of skeleton dimensionality, body mass and volume, and adipose tissue contribute significantly to the latent structure of aerobic power. A generally positive correlation of motor abilities and negative correlation of morphological measures (especially body weight) with endurance run was observed. This is consistent with the somatotype determined in long-distance runners, in whom the somatotype components are lower as compared with athletes in other athletic disciplines[15–18]. In both boys and girls aged 7–8 years, the delicate built with a low proportion of all somatotype components favors long-distance run activity[13]. At the same time, relative strength is of great importance for all manifestations of run[19].

The results of regression analysis, presented in Tables 4 and 5, provide substantial information supporting the theory of integrated development, as follows:

- Regression analyses were significant at a level of 0.001, which provides evidence about the fact that aerobic abilities in the analyzed sample could not be observed separately from general biomotor abilities and characteristics. This means that the component of aerobic work should be properly represented in the kinesiologic education of children, as a comprehensive and integral impact on the development of relevant abilities and characteristics of the children is thus ensured. The daily kinesiologic activities should thereby be observed as being extrapolated to the future, i.e. anticipating possible chil-

TABLE 4
REGRESSION COEFFICIENTS (β) AND MULTIPLE CORRELATION (ρ) OF 3-MIN RUN VARIABLE IN MORPHOLOGIC-MOTOR SPACE FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE BOYS

Variable	1 (N=566)		2 (N=560)		3 (N=561)		4 (N=518)	
	β		β		β		β	
Stature (cm)	–0.02		0.06		0.20	***	0.21	***
Body mass (kg)	–0.12		–0.19	***	–0.42	***	–0.11	
Forearm circum. (cm)	–0.02		0.05		0.12		–0.08	
Triceps skinfold (mm)	0.00		0.05		0.06		0.07	
Hand tapping (f)	0.06		0.00		0.13	**	0.02	
Standing jump (cm)	0.11	*	0.15	***	0.11	*	0.28	***
Polygon back. (s)#	–0.04		0.11	*	–0.04		–0.10	*
Sit-ups (per minute)	0.20	***	0.26	***	0.04		0.16	***
Forward bow (cm)	0.06		–0.01		–0.10	*	–0.06	
Bent arm hang (s)	0.10	*	0.18	***	0.11	*	0.10	*
ρ	0.38	***	0.45	***	0.42	***	0.53	***

– variable with the opposite metric orientation
*p<0.05; **p<0.01; ***p<0.001

TABLE 5
REGRESSION COEFFICIENTS (β) AND MULTIPLE CORRELATION (ρ) OF 3-MIN RUN VARIABLE IN MORPHOLOGIC-MOTOR SPACE FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE GIRLS

Variable	1 (N=575)		2 (N=543)		3 (N=573)		4 (N=544)	
	β		β		β		β	
Stature (cm)	–0.04		0.05		0.17	***	–0.14	*
Body mass (kg)	–0.11		–0.16	*	–0.20	**	–0.06	
Forearm circum. (cm)	0.01		0.01		–0.07		–0.04	
Triceps skinfold (mm)	0.09		0.12	*	0.13	**	–0.01	
Hand tapping (f)	0.01		–0.06		0.16	***	–0.01	
Standing jump (cm)	0.08		0.16	***	0.23	***	0.13	**
Polygon back. (s)#	–0.10	*	0.07		0.06		0.00	
Sit-ups (per minute)	0.13	**	0.27	***	0.07		0.26	***
Forward bow (cm)	0.03		–0.06		0.03		0.09	*
Bent arm hang (s)	0.07		0.23	***	0.16	***	0.10	*
ρ	0.29	***	0.48	***	0.49	***	0.43	***

– variable with the opposite metric orientation
*p<0.05; **p<0.01; ***p<0.001

dren's achievements largely based on aerobic power;

- Multiple correlations increased from first to fourth grade in boys, and from first to third grade in girls, pointing to the ever more intensive processes of aerobic power integration in the system of biomotor dimensions. The very growth and development supported by systematic kinesiologic education led to the integration of aerobic work properties to the morphological-motor system, which is one of the basic goals of kinesiologic activities in general;

- Regression coefficients show the number of predictors realizing significant criterion prediction (3-min run) to rise with elementary school grade. This means that elevating aerobic power to an even higher level also influenced all other abilities and features of the biomotor development. This is also known otherwise in kinesiology, especially in sports, where aerobic power is the basis to be upgraded first, and which almost all other achievements will ultimately rely on;
- There was gradual integration of aerobic power into the morphological system, from first to fourth grade in boys, and from first to third grade in girls, with skeleton longitudinality as a positive predictor and body mass as an interfering movement factor. Adipose tissue had no negative predictive value on prolonged activity of submaximal intensity in children aged 7–11 years, probably because the child's body is ergonomically, i.e. in energy utilization, optimized to a greater extent than the adult body, thus exhibiting higher persistence on submaximal intensity activity;
- The tests assessing the factor of strength regularly presented as good criterion predictors. Thus, aerobic power is predominantly determined by energy regulation of movement, by a combination of the mechanisms responsible for the duration and intensity of energy mobilization. The development of aerobic power was accompanied by continuous development of explosive strength and muscular endurance (static strength). In third grade, repetitive strength was substituted by psychomotor speed as a good positive predictor, with the running pace being most likely facilitated by the movement frequency. In fourth grade, besides the factors of strength, coordination in boys and flexibility in girls occurred as good predictors. So, coordination in boys and muscle tonus regulation in girls obviously reflected directly in realizing an optimal running pace, and thus optimal utilization of the energy transport system.

Discussion

The crucial results and inferred information on the relations between the morphological-motor system and aerobic power in particular age groups of children of both sexes have been previously presented. In this way, data on the effect of age, i.e. of overall growth and development, on the processes of aerobic power integration into the morphological-motor system were obtained. The process of integration of the anthropologic status subsegments into a harmonious unity undergoes a number of developmental stages with certain gender specificities. The structure of aerobic power, i.e. determination of particular predictor variables and criteria, modifies in parallel with the development of particular morphological properties and motor abilities. The development of a particular morphological characteristic or motor ability should reach a level enabling it to influence the criterion, i.e. aerobic power. Thus, particular characteristics and abilities are being included in the criterion prediction following the specific age-dependent sequence and intensity.

So, first-grade boys show predominant usage of repetitive strength of the trunk on endurance run, with a lower use of explosive strength, static strength and/or muscle endurance. In second-grade boys, intensive and concurrent development of all strength factors and aerobic power occurs, manifesting as high mutual determination. Now, the boys use all strength factors to a greater extent and in the order of importance, i.e. repetitive, static and explosive. In third grade, body height achieves a level at which it favorably influences the ability of long run, whereas body weight gain has a highly unfavorable effect. Considering these morphological properties, the boys now use the ability of movement frequency, i.e. the psychomotor speed, as well as explosive and static strength on 3-min run. Thus, the mode of energy utilization relative to the criterion variable has changed. This will be fully expressed in fourth-grade boys, when they make a predominant use of explosive strength, followed by repetitive and static strength, with running technique optimization, on 3-min run. The relationship of the factors of strength and 3-min run thus obtained is consistent with the results of Katić et al.[14], where they found a positive correlation between explosive strength variables and sprint, and between repetitive strength and long-distance run in draftees.

All this reveals that during the process of development, 3-min run performance in boys gradually switches from predominantly aerobic to predominantly anaerobic energy utilization. Of course, the mechanisms responsible for aerobic and anaerobic energy transformation are always present in running, i.e. predominantly aerobic in long-distance run, predominantly anaerobic in short-distance run, and both in middle-distance run.

Presuming that the strength variables used also evaluate the strength of particular regions of the body to a certain extent, it is obvious that in first-grade boys there was a predominant impact of trunk strength on the criterion, whereas in fourth-grade boys a morphological-motor structure had formed, whereby the 3-min run was mostly determined by the strength of legs, followed by the trunk and arm strength, accompanied by a coordinated running technique. This appears quite logical from the viewpoint of biomechanics. The more so, it is widely known that in middle- and long-distance runners, lower extremities are more developed than other parts of the body in terms of leg length, femur circumference, and relative strength expression.

In girls, the process of aerobic power integration in the morphological-motor system proceeded in a similar way as in boys, however, from the first to third grade. In first-grade girls, aerobic power was determined exclusively by repetitive strength of the trunk with cortical movement regulation. In second-grade, a marked and intensive advancement in the development of all strength factors and aerobic power was recorded, exerting an impact on their mutual determination, i.e. between morphological-motor system and aerobic power. These changes were considerably more pronounced in girls than in boys, indicating that the systematic first-grade kinesiologic activities probably were more appropriate in terms of frequency and contents for girls than for boys.

In third-grade girls, like in third-grade boys, explosive strength along with movement frequency and static strength assumed the leading role in predicting aerobic power. This phenomenon was also more pronounced in girls than in boys. In girls too, body height and adipose tissue had a favorable effect, and body weight an unfavorable effect on the criterion.

In fourth grade, the increase in aerobic power was predominantly achieved by use of repetitive strength of the trunk, followed by explosive strength and static strength, all this with muscle tonus regulation. Clearly, 3-min run imposed a load on the girls, which required predominantly aerobic energy utilization. The development of psychomotor speed, which was found to continue in the fourth-grade, had no effect on aerobic power anymore. This is quite logical, as the speed and endurance are two opposed abilities, i.e. the greater the speed, the lower the endurance, and vice versa.

In comparison with boys, the processes of aerobic power integration in the morphological-motor system proceeded at a faster rate and were more pronounced in girls, especially during the first- to third-grade period. In fourth grade, the structure of the morphological-motor complex, which determines the 3-min run results, differed significantly between the boys and girls, which is believed to be due to sex specificities.

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INTEGRACIJA AEROBNIH SPOSOBNOSTI U MORFOLOŠKO-MOTORIČKI SUSTAV KOD DJECE UZRASTA 7–11 GODINA

S A Ž E T A K

Na uzorku od 4.440 djece oba spola (sastavljenog od 8 poduzoraka), polaznika prvog do četvrtog razreda osnovnih škola Primorsko-goranske Županije R. Hrvatske, starosne dobi 7–11 godina, primijenjene su 4 morfološke i 6 motoričkih varijabli koje pokrivaju morfološko-motorički prostor. Funkcionalne sposobnosti su procijenjene trčanjem na 3 minute. Svrha rada bila je analiza integracija aerobnih sposobnosti u ostale procijenjene dimenzije. U tom smislu u svakom razredu i za svaki spol analizirane su relacije prediktorskog skupa morfološko-motoričkih varijabli s trčanjem na 3 minute kao kriterijem. Podaci su obrađeni regresijskom analizom. Rezultati su jasno pokazali kako ovisno o starosnoj dobi rastu vrijednosti kriterijske varijable i kako je predikcija kriterija primijenjenim skupom prediktorskih varijabli sve bolja. Jednako tako je primjetno da se usporedo sa starosnom dobi sve veći broj prediktora uključuje u predikciju istrajnog trčanja na značajnoj razini. Najbolji prediktori kriterija su faktori snage sa dominacijom eksplozivne snage kod dječaka, a faktori snage sa dominacijom repetitivne snage kod djevojčica. Istaknuto je, da se podizanjem aerobnih sposobnosti na sve višu razinu utječe i na razvoj morfološko-motoričkog sustava, a time i na podizanje funkcije organizma kao cjeline. Pritom će adekvatne sustavne kineziološke aktivnosti ubrzati procese integracije aerobnih sposobnosti u morfološko-motorički sustav. Spomenuta integracija se, kako je vidljivo iz rezultata ovog rada kod djevojčica odvija brže i intenzivnije nego kod dječaka.