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Phylogenetically Conditioned Possibilities of the Realization and of the Development of Complex Movements at the Age of 7 Years

R. Katić[1], D. Bonacin[1] and S. Blažević[2]

[1] Faculty of Natural Sciences, Mathematics and Education, University of Split, Split, Croatia
[2] Faculty of Economics, University of Rijeka, Rijeka, Croatia

A B S T R A C T

Upon entering a school the seven-year olds (+/- 2 months) underwent a systematic, experimental, specially programmed, eighteen-month-long transformational procedure. The objective of the procedure was to develop the abilities and to observe the growth and the development of children, both girls and boys. The data were processed by means of discriminant analyses in each of the three control points. There was a total sample of 487 children. With regard to the phylogenetic characteristics of a human, it may be said that the basic abilities connected with phylogenetic development may be clearly recognized, precisely in such a way that children replicate this development throughout their earliest childhood. Most probably, the basic ability was the ability to maintain a postural balance, followed by the ability of movement control. Then came object manipulation by upper extremities, followed by the significance of resistance to inertial forces while moving, and ultimately the control of complex movements of the whole body.

Introduction

Man is a biological organism that went through a long, complex and an extremely interesting process of development. Many of the determinants of his development remain incorporated in his anthropological structure, thus also in the sub-segments which are even today responsible for the realization of some basic kinematic possibilities and characteristics. It might even be said that they represent a specific permanent basis of man as a being.

From the developmental and phylogenetic point of view, it is possible to record some characteristic qualities on the basis of which the entire kinematic devel-

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opment of a person may be consistently followed. If the basic difference between man and other living creatures is observed from this viewpoint, then it may be said that it were his abilities that made it possible to acquire numerous skills, which further induced his unparalleled intellectual and cognitive development. It might even be said that some of those abilities were always developed up to the level which enabled the development of subsequent abilities, and this progressive continuity persevered, and it does so today[1–6].

The first such ability that is of a special interest to us is the ability of maintaining the upright posture. In terms of kinematics, and within the limits both of the anthropological and of the kinesiological determinants, it might be said that what we are dealing with here is the following: *Co-ordination-related movement component which is characterized by the control of maintaining a balance posture on the basis of the vestibular, oculomotor and other perceptions of body posture which approach the limits of the safety angle.* This is usually called *balance*[7,8]. It was not before the issues of balance were appropriately and satisfactorily dealt with that further development of abilities was to be expected, among them definitely also the one that can be simply described as: *Co-ordination- and information-related movement component which is characterized by the control and by the maximal speed of the flow rate of communication channels inside an organism, significantly directed towards the extremities that were adapted, during the course of evolution, dominantly for moving the whole organism.*

This is usually called *lower extremities movement control*, which requires that the issue of quick conveyance (afferent/efferent) of impulses towards the effectors and away from the effectors, upon which the elementary spatial movement of the whole body depends, be appropriately solved, especially in ways that provide the maximal movement speed of the whole body[9–11]. Having appropriately dealt with this issue as well, one may start to seriously examine the abilities to manipulate objects from one's environment. These abilities may be described as follows: *Co-ordination- and information-related movement component which is characterized by the control and by the maximal speed of the flow rate of communication channels inside an organism, directed towards the extremities that were adapted, during the course of evolution, dominantly for object manipulation.* This is usually called *object manipulation using the upper extremities*. In this respect we were also interested in the control and in the speed of the flow rate of the corresponding communication channels, because for object manipulation the issue of an extremely fast conveyance (afferent/efferent) of impulses towards the effectors and away from the effectors, upon which the control of micro-segments (such as hand or fingers) depends, should be appropriately solved, thus providing the maximal possible speed of object manipulation[12–14].

Having dealt with the control of both the lower and of the upper extremities in a quality way, the issue can be raised of the ability to quickly change the direction of movement in a varying environment in which man dwells and performs various activities, from movement to object manipulation. This may be simply described as: *Co-ordination- and energy-related component of movement execution characterized by the control of the body in the conditions of a more difficult way of moving and halting, that is, the existence of resistance to inertial movement in limited space and time co-ordinates.* This is usually called *agility (dexterity).* Finally, having dealt appropriately with this issue as well, we may start to consider even the most complex movements that imply activation of the whole body and its complex moving in space. These abilities may be described as: *Co-ordination-related component of movement execution characterized by the control of the whole body in different conditions, meeting the complex requirements of congruous involvement of proper segments in order to move in space or to accomplish a complex task.*

This is usually called *co-ordination*. To be able to understand this term, we usually use the parameters for the assessment of co-ordination abilities[18–22]. What is particularly interesting is the fact that, most probably, to sufficiently develop each one of the mentioned abilities each ability mentioned prior to the one in question should be developed to an appropriate level (----), although further parallel development of these abilities is not excluded (...), Figure 1.

In congruence with the previous assumptions it should be stressed that the development of the abilities in children is particularly important at the earliest age, since the manifestations of what had been accomplished affect all further achievements. It is well known that some abilities are expressly genetically predetermined and that the possibility of affecting them decreases with maturation, consequently decreasing the prospective achievements at any age, also in the middle age and later. During childhood, man replicates the described phylogenetic development, and out of all anthropological abilities with a significantly high degree of genetic conditioning, as far as kinesiological science and practice are concerned, those that are responsible for the quality of movement control are among the most important ones[23–26].

In the largest sense we usually call them co-ordination abilities, although what we are talking about here is a very wide range of mechanisms responsible for the realization of movement dominantly in terms of information employment. The bases of these abilities are evidently developed at the earliest age, so that a systematic influence is of considerable im-

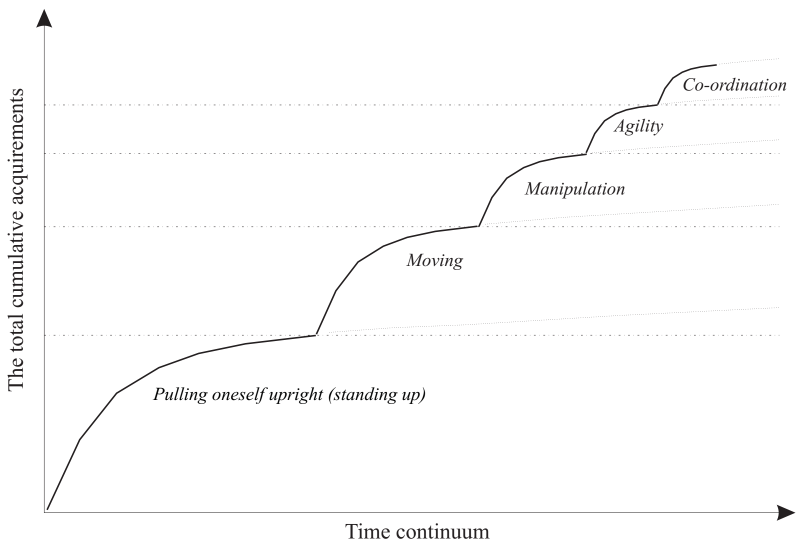

Fig. 1. Hypothetical development of some basic kinetic abilities.

portance. If systematic stimuli cannot be qualitatively applied from the first to the fifth year of age due to various reasons, then they should be qualitatively applied upon starting school. This especially stands to reason because there exists a cause-and-effect relationship in which, on the one hand, physical exercising supports the development of the specified abilities, and on the other, the degree of development provides space for further influence, so that these two characteristics continuously supplement each other, thus providing a greater acquirement[27,29].

Contemporary lifestyle, particularly in urban areas, has a restraining effect on children from 6 to 12 years of age, which at a later age appears to be an irretrievable deficit. Any effort that would stimulate physical activity in children at this age is therefore important. As it is well known, at the age of approximately 6–7 years, the process of differentiating among various abilities and characteristics in children is slowly nearing its final phase, and the process of amalgamation starts, thus providing the development with its final contours. Therefore, the last period in which something can be done systematically for the benefit of children in this respect is precisely the period between 6 and 12 years of age, that is, the very period in which a child may be exposed to complex systematic positive influences, particularly as regards the quality of movement control. Then puberty begins and the general stabilization of functions occurs, so that there will most probably be no more progress in terms of quality[30].

This is the reason why this paper tries to topicalize the issue of the quality of control of some complex movements, as well as to analyze the differences among co-ordination abilities with regard to time, that is, the duration of a treatment intended for children who are 7 years of age. Even the smallest progress at the earliest school age may be a huge capital in the later periods of life.

Material and Methods

The sample of examinees was comprised of 487 children, primary school first formers from Split who were 7 years 2 months old at the beginning of the experimental procedure. This sample was divided in four sub-samples: experimental group – boys G1 (n=131), control group – boys G2 (n=118), experimental group – girls G3 (n=123) and control group – girls G4 (n=115). None of the children had any visible aberrations and they were all able to follow a classical physical education curriculum in primary school.

The sample of variables[27] used for the assessment was selected in such a way as to cover some co-ordination abilities, that is, the abilities of movement control, with a dominantly information-employment component: side steps (MKUS), standing on the bench (MP20), polygon backwards (MPOL), hand tapping (MTAP) and foot tapping (MTAN). All measurements were carried out by qualified experts who had significant experience in collecting the indicated initial data.

Data processing methods implied everything from metric characteristics, to elementary statistical indicators, to multivariate methods; for the purpose of this paper, the data connected with arithmetic means and standard deviations, discriminant functions, significance testing and the centroids of groups on these functions were condensed. Table 1 contains arithmetic means and standard deviations for each group (G1–4) and for the total sample and Table 2 contains discriminant functions (F1, F2), determination coefficients (Delta), chi-square tests values (^{2}), probability (P), and centroids of groups on discriminant functions (G1c–4c).

Transformational processes[27] were defined in such a way that the experimental

TABLE 1
STATISTICAL PARAMETERS FOR EACH GROUP IN 3 CONSECUTIVE MEASUREMENTS

		X1	SD1	X2	SD2	X3	SD3	X3-X1	X2-X1	X3-X2
Male experimental group	MKUS*	16.36	1.96	14.14	1.56	13.38	1.71	–2.98	–2.22	–0.76
	MP2O	1.62	0.69	2.20	0.78	2.91	0.98	1.29	0.58	0.71
	MPOL*	22.84	5.77	16.52	3.74	14.38	4.02	–8.46	–6.32	–2.14
	MTAP	18.78	2.54	21.67	2.71	22.94	3.03	4.16	2.89	1.27
	MTAN	15.49	1.96	17.53	1.88	18.75	2.09	3.26	2.04	1.22
Male control group	MKUS*	16.08	1.99	14.14	1.67	13.42	1.87	–2.66	–1.94	–0.72
	MP2O	1.85	0.69	2.06	0.80	2.75	0.95	0.90	0.21	0.69
	MPOL*	23.05	7.12	17.39	4.30	15.43	4.57	–7.62	–5.66	–1.96
	MTAP	19.81	3.08	20.88	2.30	21.83	2.38	2.02	1.07	0.95
	MTAN	15.96	1.93	17.19	1.82	18.23	2.06	2.27	1.23	1.04
Female experimental group	MKUS*	17.09	2.05	14.70	1.63	13.87	1.83	–3.22	–2.39	–0.83
	MP2O	1.54	0.61	2.13	0.84	2.87	1.04	1.33	0.59	0.74
	MPOL*	25.47	6.66	18.62	4.47	16.30	4.56	–9.17	–6.85	–2.32
	MTAP	18.49	2.21	22.12	2.90	23.60	3.45	5.11	3.63	1.48
	MTAN	15.96	1.56	18.33	1.94	19.63	2.31	3.67	2.37	1.30
Female control group	MKUS*	16.21	1.98	14.60	1.60	13.96	1.82	–2.25	–1.61	–0.64
	MP2O	1.76	0.74	1.87	0.66	2.56	0.87	0.80	0.11	0.69
	MPOL*	27.33	7.91	20.64	4.81	18.31	5.33	–9.02	–6.69	–2.33
	MTAP	19.10	2.49	20.62	2.45	21.52	2.69	2.42	1.52	0.90
	MTAN	16.05	1.86	17.53	1.90	18.66	2.09	2.61	1.48	1.13
Total	MKUS*	16.44	2.03	14.39	1.64	13.65	1.83	–2.79	–2.05	–0.74
	MP2O	1.69	0.70	2.07	0.78	2.78	0.97	1.09	0.38	0.71
	MPOL*	24.62	7.11	18.24	4.60	16.05	4.84	–8.57	–6.38	–2.19
	MTAP	19.03	2.64	21.34	2.68	22.50	3.04	3.47	2.31	1.16
	MTAN	15.86	1.85	17.65	1.93	18.82	2.20	2.96	1.79	1.17

MKUS = side steps; MP20 = standing on the bench; MPOL = polygon backwards; MTAP = hand tapping; MTAN = foot tapping.

X1, X2, X3 = means for the 1st, 2nd and 3rd measurement; SD1, SD2, SD3 = standard deviations for the 1st, 2nd and 3rd measurement; * = variable with the opposite metric orientation

group underwent a specially programmed transformational procedure within the subject Physical Education, whereas the control groups underwent the classical Physical Education curriculum in the corresponding primary school form.

TABLE 2
DISCRIMINANT FUNCTIONS AND ANOVA FOR 3 CONSECUTIVE MEASUREMENTS

Variables	M1		M2		M3	
	F1	F2	F1	F2	F1	F2
MKUS*	0.12	**–0.66**	**0.37**	0.12	**0.39**	–0.04
MP2O	0.02	**0.61**	–0.22	**0.42**	–0.18	**0.38**
MPOL*	**0.86**	–0.08	**0.73**	–0.46	**0.70**	–0.47
MTAP	–0.10	**0.62**	–0.01	**0.75**	0.03	**0.87**
MTAN	**0.32**	0.10	0.32	**0.58**	0.37	**0.58**
Delta	0.30	0.28	0.42	0.30	0.42	0.35
^{2}	89.26	34.52	130.83	44.63	136.17	60.19
P	0.02	0.04	0.00	0.00	0.00	0.00
Standard. centroids	F1	F2	F1	F2	F1	F2
Male experimental group	–0.08	–0.02	–0.08	0.02	–0.07	0.04
Male control group	0.00	0.08	–0.07	–0.05	–0.07	–0.06
Female experimental group	0.01	–0.09	0.08	0.09	0.08	0.10
Female control group	0.07	0.03	0.07	–0.06	0.07	–0.08
ANOVA	F^A	P^A	F^A	P^A	F^A	P^A
MKUS*	6.13	0.00	4.07	0.01	3.86	0.01
MP2O	4.92	0.00	3.98	0.01	3.88	0.01
MPOL*	11.48	0.00	20.34	0.00	25.59	0.00
MTAP	5.74	0.00	8.34	0.00	13.01	0.00
MTAN	2.38	0.07	8.00	0.00	8.99	0.00

MKUS = side steps; MP20 = standing on the bench; MPOL = polygon backwards; MTAP = hand tapping; MTAN = foot tapping.

F1, F2 = discriminant functions; Delta = canonical discrimination; ^{2} = ^{2} for significance testing; P = probability; F^A = F-test for ANOVA; P^A = probability for ANOVA; * = variable with the opposite metric orientation

The experimental program included activities and stimuli chosen from athletics (walks and running, jumping, throwing), from artistic gymnastics (floor exercises, exercises on pieces of apparatus, vaults), from games (basic techniques, elementary games, relay games, team games), all appropriate to age. The experimental transformational procedures were programmed before the onset of the experiment and carried out by physical education teachers. The classical program (physical education curriculum) was carried out by the first-to-fourth form teachers.

Control points in which the measurements were done were defined in the periods each lasting nine months (10 days), so that the total period in which the data were processed for the purpose of this paper was 18 months, that is, one and a half years.

Results

The data displayed in Table 1 show positive progress in all groups as regards the execution of movements that describe the assessed co-ordination abilities. It is evident that, on the one hand, even a nine-month treatment led to a recognizable progress in some abilities, and on the other, that after only nine months the possible progress in some abilities was mostly stabilized. As for balance (MP20), slight stabilization may be noted after 18 months, which points to the fact that, taking into account the applied transition operators, it is much more difficult to affect this ability. This also shows that this ability appears to be the basic ability, as described in the introduction, because the quality of the whole system for the control of fine and complex movements depends on its quality. A similar, but a somewhat smaller progress may be seen in leg frequency (MTAN) which makes it possible to believe that the next most important ability is the ability to move and control lower extremities. Likewise, the progress as regards the measurement results of the polygon backwards (MPOL) will be the one to be stabilized most rapidly, which additionally attests to the fact that general co-ordination of the whole body might be žthe youngest' of all the treated abilities.

What can be concluded on the basis of data displayed in Table 2 is that it is possible to recognize in each of the three measurements two significant discriminant functions. Slight restructuring of co-ordination abilities after the first part of the treatment (after nine months) may be noticed. Although there is no doubt that there exist the differences as regards further positive effects, the stabilization is mostly achieved already after nine months. Thus, for example, on the basis of the centroids of groups in the second and in the third measurement we may easily recognize the first discriminant function as the one that distinguishes the male from the female examinees, and the second discriminant function as the one that distinguishes the experimental from the control groups. Additionally, it is evident that the first discriminant function in the second and in the third measurement describes agility (MKUS) and the polygon backwards (MPOL), whereas the second discriminant function in these measurements describes balance (MP20), hand tapping (MTAO) and foot tapping (MTAN). These functions evidently represent rather stable interrelations, although one cannot help noticing, on the second discriminant function of differences between the groups, that the contribution of balance decreases, whereas the contribution of hand and foot tapping increases. On the first function, the contribution of the polygon backwards decreases, whereas the contribution of agility increases.

What agility and the polygon backwards have in common is a significant portion of energy-related demands for the execution of very complex movements, whereas balance and hand and foot tapping share a serial processing of the pieces of information that have relatively low demands as regards the energy-related saturation during the execution of movements.

Discussion

Within the set conceptual, and therefore, also methodological framework of this paper, what is particularly emphasized is the fact that no publications were found that would generally have an altogether higher degree of conceptual transparency. This is so because the comprehensive issue studied here was usually dealt with from some, mostly partial, aspects which did not include the complete considerations presented in this paper. The analysis of the results on the one hand, and the discussion about these results on the other should be approached dominantly from the general anthropological point of view, simultaneously taking into account the well-known facts about phylogenetic development.

As it is well known, the feeling of balance is regulated by a system that is characterized by the fact that even while standing, impulses are continuously transmitted from the reticular structure and the neighboring nuclei in the central nervous system into the spinal cord. The largest number of autoexcitable stimuli comes from the vestibular mechanism. However, the degree of activity of the extensor muscles is determined by a mechanism that maintains balance. The final result of the initial disturbance of balance is the realization of the system of reflex actions which helps not only to strike the balance, but also to anticipate the loss of balance. This undoubtedly means that such mechanism is phylogenetically very old, and, from the point of view of contemporary man, it boils down to reflex actions. This on no account implies any particular analysis in the real--time regimen. Additionally, this means that in the earliest childhood, before final patterns have been established, this mechanism may be affected to a possible extent, after the process of pulling oneself upright (standing up) has finally been completed at the age of approximately 12–14 months.

According to the data obtained in this paper, a systematic kinesiological treatment may without any doubt contribute to the whole process. As it is evident, both the classical contents of the physical education classes (curriculum) and the specially programmed treatment brought about positive effects in this respect. These positive effects were slightly higher in girls than in boys, and they were also somewhat more expressed in experimental groups. Therefore, even at the age of seven years the development of balance can still be affected, but a year or more of systematic treatment is the time necessary to achieve any effect.

Movement (walking, running) control is, however, a complex process which involves not only the motor functions of locomotion, but also the very mechanism that is permanently active and that is needed to keep the balance. Transmission to the system of effectors undoubtedly requires, above all, apart from forming the quality engrams, an exceptional speed of signal transmission.

Motor fibers of the pyramidal and of the extrapyramidal tract are, of course, the thickest myelinisated and the fastest fibers in general (a- 70–120 m/s, a- 40–70 m/s, a- 15–40 m/s); this also holds true for the cortico-cerebral and for the spino-cerebral pathway in movement acquisition. It is beyond any doubt, that the quality of movement regulation and the execution of the activity in the varying environment in which a person lives depend on the speed of impulse transmission. The characteristics regarding object manipulation using the upper extremities may be described in the completely same way, which is particularly important for the forearm, that is, for the hand and for the fingers. Naturally, this was phylogenetically possible only after the upper extremities had been sufficiently freed from the tasks connected with maintaining the balance and connected with movement. The arms are therefore better represented in the sensorimotor areas of the brain, which thus makes it possible, unlike with legs, to perform a fine regulation of activities. The legs, on the other hand, may produce greater force, which is directly connected with setting in motion of a larger mass, that is, of the entire body. In the treated samples it was evident that a significantly better influence was exerted on the ability of impulse transmission in experimental groups than in control groups.

Likewise, as it was the case with balance, the influence on the impulse transmission towards lower extremities is less expressed, which gives evidence about a poorer ecosensitivity of this mechanism, which, accordingly, makes it stand together with balance, as presumed. The impulse transmission into upper extremities was significantly improved by means of the applied treatment, which is after all connected with the well-known attitudes about the possibility of development of these abilities in children of this age. At any rate, children aged 6–7 years learn intensively how to write, the curricula are directed towards the acquisition of other skills as well, among them the ones that are directly kinesiologically supported.

As it is obvious from the results, it is the three described abilities (balance, impulse transmission into lower and upper extremities) that together differentiate between the entities on discriminant functions, which may help justify the assumption about the integration of these abilities into a unified system. This, of course, stands to reason if we take into account the development-related fact about a set of abilities that together make up an elementary system of characteristics necessary to actively negotiate one's environment. By reaching an appropriate level of autonomy, an entity evidently increases his/her abilities, that is, he/she includes a more expressed energy-related component into the total movement control, which, in this case, is described as an ability to overcome the inertial forces. This is also understandable since higher intensity is needed to be able to function successfully in a varying environment in the future, but attention should be paid not to exceed the adequate control and supervision of information. This ability is evidently operated by means of space and time summation, as well as by means of facilitative-excitative mechanisms, and this undoubtedly makes it one of the co-ordination abilities; however, since a significant energy recruitment is also at work here, we can say that what we are talking about is the lower-level co-ordination. This is a very complex mechanism that implies the exertion of a greater force, but also the greater transmission speed and the activation of myometric and plyometric movements. Obviously, this ability is a continuation of the previously indicated abilities, but it also displays characteristics that the previously specified abilities did not have, namely, the integrative functioning of several sub-mechanisms for movement regulation.

In all the samples in this research major effects were obtained in as many as only nine months, which gives evidence about the possibility of a systematic impact. It may also be noted that positive effects were obtained both in the experimental and in control groups, which speaks in favor of the fact that this ability may be more easily affected, and that, consequently, it may be developed later in life as well. This is so because in the time to come a seven-year-old child will significantly change and develop morphologically, and this will cause the changes in the locomotor system, in lever functions, and in the forces exerted, so that the final development of this ability will, most likely, take place after puberty. Naturally, the possibility of impact decreases with age. It cannot be said that differences according to gender are clearly visible.

Likewise, the most complex activities, assessed in this paper by means of the test *polygon backwards*, show the biggest progress, mostly already after the first control point, that is, after nine months. This points to the fact that co-ordinated activity of the whole body is definitely the ability that develops last and that its maximum will be reached later than the maximum of all the treated abilities.

Although such a complex movement co-ordination is frequently considered to be, in a narrower sense, highly and even žtoo highly' genetically determined, this paper clearly refutes such an opinion and shows that positive effects and the improvement of functions are possible provided that an appropriate treatment be used, and that it be used relatively quickly at a relatively early age. An opinion that an even more significant progress in later phases of the development of a child is possible is not ruled out. Girls are somewhat more sensitive to positive effects, which is probably caused by a generally known movement insufficiency of female children at pre-school age, which is primarily a social, and not specifically a kinesiological problem. These outstanding pieces of information provoke various considerations, among them also the one that treats a child as an individual subject that must be the focus of interest, the goal here being to develop the genetically facilitated potentials.

Finally, the lower-level co-ordination (agility) and the co-ordination of the whole body together appear as a factor of differentiation on discriminant functions, which means that they are, to some extent, concurrent, namely, that they probably have both a common superposed mechanism and a common phylogenetic foundation.

The first discriminant function classified the entities in such a way that it gave preference to boys over girls as regards the ability to actively negotiate one's environment, which is perfectly understandable taking into account the role of a male person and the abilities that he usually possesses.

The second discriminant function, however, classified the entities exclusively according to the type of a treatment. The specially conducted treatment produced better results than the regular physical education classes, irrespective of gender, which means that, provided that gender characteristics are left out, an excellent indicator of the possibility of influence exertion is obtained. If we remember that we are dealing with complex movements, then the importance of this conclusion is particularly emphasized. This helps create a complete picture not only of the possibility to develop complex movement in children, but also of the possibility of biological growth and development, which, in the biological sense, cannot be separated anyway.

On the whole, it may be said that it is of an outstanding importance to perceive the possibility of the development of co-ordination abilities precisely in consistence with the time spent under treatment, since this happens to be one of the basic kinesiological characteristics of physical exercising.

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R. Katić

Faculty of Natural Sciences, Mathematics and Education University of Split, Teslina 12, 21000 Split, Croatia

FILOGENETSKI UVJETOVANE MOGUĆNOSTI REALIZACIJE I RAZVOJA SLOŽENIH GIBANJA U UZRASTU OD 7 GODINA

S A Ž E T A K

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