COMPUTER SIMULATION OF JUNIOR GYMNASTS' TRAINING PROCESS

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Original article

Abstract

The purpose of the research is to develop methodological approach to creation of an algorithm of informational provisioning of children's and adolescents' training of motor actions. The research was conducted in compliance with a plan of factorial experiment of 2^2 type. The received materials were used for simulation of gymnast training process. At initial stage of training, we analyzed 530 sessions (92 gymnasts of 7-10 years old age). At the stage of basic training, we analyzed 580 trainings (78 gymnasts of 11-13 years old age). For determination of different training modes' influence on change of functional state of cardio-vascular and nervous-muscular systems we conducted a five-year longitudinal prospective research (60 gymnasts). We produced an algorithm of informational provisioning of child and adolescent training to motor actions. The algorithm is based on computer simulation of a training process. We found that the progress in fulfillment of exercise depends statistically significantly on the group of following indicators: level of fitness, organization of load and orientation of training. We provide data about change of training results and pulse frequency. We show that factorial experiment's results were reliable and effective in determination of different working modes' influence on functional state and gymnast ability for mastering of motor actions. Algorithm of calculation of normative loads for gymnasts was worked out. The offered algorithm of computer simulation of training process's simulation permits receiving new information about fitness, organization of load and orientation of training influence on effectiveness of motor skill formation.

Keywords: *gymnast, information, motion, training, load, schoolchildren, training.*

INTRODUCTION

Application of computer programs in schoolchildren's physical education and sport training enables a control of pupils' physical condition, corrections in educational and health related processes, individualization of training, automatization of analysis and assessment of received results (Shandrigos', 2000, 2002, 2004; Vovk, 2002; Lucenko, 2003; Meng & Li, 2013). Data in scientific literature witnesses about urgency of problem of physical culture trainings' informational provisioning. Vovk (2002), Ashanin, Golosov and Gorbatenko (2010), Ashanin, Filenko and Nesterenko (2011), Goncharova, Yukhno and Lukjantseva (2012), Borysova and Vlasyuk (2014), point to demand in implementation of automatization in information technology (IT) and creation of data base about children and adolescent physical condition. Saptsin and Tsipoviaz (2009) offer approaches to objective assessment of sport results and pedagogic testing. These are always subjected to random component and depend on external, internal and subjective factors. The authors give analysis of uncertainty considering new concepts and mathematic approaches, based on physical and quantum-mechanical analogies.

At the present time research in development of methodological approaches for creation of applied programs in the field of physical education and sports (Hong, 2013) is being carried out. The efforts are directed to produce the programs for taking decisions in the planning of training (Wu, 2013), simulations in the field of bio-mechanics (Merala & Piziali, 1996; Kirk, 1999) and assessment of pupils' functional state (Wright, 1999; Lucenko, 2003; Rink, Jones, Kirby, Mitchell, & Doutis, 2007). The data has been accumulated about schoolchildren physical education's effectiveness depending on the scope and orientation of motor functioning. On the basis of discriminant analysis equations have been developed which permit the control of child and adolescent fitness (Milić, Milavić, & Grgantov 2011; de Brujin & Gartner, 2011; Dorita, Pienaar, & Truter, 2011; Lulzim, 2013; Khudolii & Ivashchenko, 2014; Ivashchenko, Yermakova, Cieslicka, & Muszkieta, 2015). The value of application of metrical assessment of measurements' reliability has been proved – stability, co-ordination and self-description of control results. With these, certain quantitative information permits individualization of junior sportsmen's training according to requirements of controlled processes (Zaporozhanov & Boraczynski, 2012). It was recommended to assess reliability of measurements by calculation of linear correlation between consequent results in series. Stability of measurements should be assessed with the same method between results of accuracy in the first and seventh attempt (Zaporozhanov, 2013).

Analysis of mathematical models allows selection of physical exercises on the basis of kinematic movement characteristics (Iermakov, 2001, 2010); arrangement of means of orientation priority during educational term and development of movement abilities (Khudolii, 2005, 2009, 2012; Khudolii & Iermakov, 2011; Rumba, 2013; Karpenko & Rumba, 2014). Regularities of motor skills' development have been substantiated depending on adaptation processes (Platonov & Bulatova, 1995; Linec', 1997; Khudolii & Ivashchenko, 2014). Also the data about model building and their application in gymnastics have been presented: assessment of efficiency of sport task's fulfillment (LaForge-MacKenzie & Sullivan, 2014) and fulfillment of imitation exercises (Jensen, Scott, Krustrup, & Mohr, 2013); cause-effect relations of self-assessment of gymnastic exercises' fulfillment (Marsh, Chanal, & Sarrazin 2006); control of movement with feedback (Miyazaki, Sampei, & Koga, 2001); priorities of affective and cognitive training (O'Leary & Griggs, 2010); optimization of women-gymnasts' loading (Sanchez et al., 2013); exposure of mechanical and physical quantities in jumps on spring built on the basis of Hay and Reid method (Takei, Blucker, Nohara, & Yamashita 2000). Tereschenko, Otsupok, Krupenio, Levchuk, & Boloban (2013) note that the content of educational material contributes to mastering the tasks of athlete sensoric-motor coordination and is a basis for effective formation of motor skills and ability of gymnastic exercise mastering. Kozhanova (2013) proposed approaches for defining the effectiveness of female gymnastic competitive activity. Normative indicators in training of children's and adolescents' motor skills have been reported (Ivashchenko, 1988; Ivashchenko & Karpunec', 2001; Khudolii, 2005; Khudolii & Ivashchenko, 2014). Conception of simulation of children's and adolescents' motor skills' training has been worked out (Khudolii, 2005; Khudolii & Ivashchenko, 2014; Ivashchenko, Yermakova, Cieslicka, & Muszkieta, 2015; Khudolii, Iermakov, &

Ananchenko, 2015), as well as a program of scientific research in the field of simulation of motor skills' training (Khudolii & Karpunec', 2002; Khudolii & Ivashchenko, 2004).

The models of educational process and training of young gymnasts can be divided to:

a) Modification model of the effectiveness of education depending on muscular, special motive and functional training of young gymnasts;

b) Modification model of the effectiveness of education depending on the quantity of training using optimal loading that provides favorable conditions for mastering the movements;

c) Modification model of the effectiveness of competitive activity depending on competitive loadings of young gymnasts.

Logistic function has been used for creation of the models a) and b), for model c) regression equation was used from the results of an analysis of full factorial experiment of 2^k type. Thus, sufficient amount of material has been accumulated to produce the algorithm of child and adolescent training and to create the appropriate software.

Hypothesis of our research is based on the following assumptions:

- When education is done on the basis of informed processes about proceeding of adaptive reactions of an organism, the effectiveness will raise;
- Objectivity of information provided by the analysis of mathematical models.

The purpose of the research is to develop methodological approaches to creation an algorithm of informational provisioning of children's and adolescents' training in motor actions.

METHODS

The methods of the research: for solution of our tasks we used dialectic method (principle of system and causality), systemic approach, simulation, generalization, analysis and synthesis, pedagogic experiment, methods of mathematic planning of experiment and testing. Systemic approach was used to find integrative, systemic characteristics of object of the research, to determine the tasks formulated in the process of algorithms and software for informational maintenance of children's and adolescents' training of motor skills.

We used the factorial experiment of 2^2 type (see table 1). The received materials were used for simulation of junior (7-13 years old) gymnastics training. At the initial stage of training we analyzed 530 training sessions. Ninety-two gymnasts 7-10 years old participated in the research. At the stage of basic training we analyzed above 580 training sessions with 78 junior gymnasts 11-13 years old. This analysis enabled the production of a model of junior gymnast training at initial and basic stages. To determine the effect of different regimes of training exercises on the change of the functional state of the cardiovascular system and the effectiveness of the training we conducted a five-year prospective experiment where 60 junior athletes participated. Heart rate was recorded after each session on the training equipment. To assess the effectiveness of the learning process we recorded the level of exercises. The level of training is defined as the ratio of successfully performed exercises to the total number of exercies.

For evaluation of training load pulsometry is commonly used in gymnastics (Khudolii, 2005; Khudolii & Ivashchenko, 2014). When young gymnasts perform exercises on the equipment in the zone of heart rate within 140-160 beats/minute, deterioration in the quality of the execution for 0.3-0.6 points is observed; quality of exercises done in the zone of heart rate within 120-135 beats/min is not affected; training in the zone of heart rate within 100-119 beats/min improves the quality of exercises for 0.3-0.4 points (Khudolii & Ivashchenko, 2014).

The study protocol was approved by the Ethical Committee of H.S. Skovoroda Kharkiv National Pedagogical University.

In addition, children and their parents or legal guardians were fully informed about all the features of the study, and a signed informed-consent document was obtained from all the parents.

RESULTS

Systemic analysis allows to determine the following items:

- Influence of different training modes on the exercise fulfillment's quality and pulse frequency;
- Optimal rate of results' increment (optimal step of result's increment is a size equal to X+s. Where X – normal, s – standard deviation);
- Time correlation of different kinds of training in gymnastic all-round (forming motive skills, repetition of exercises, development of endurance);
- Working mode, ensuring optimal increment of results (rotation of physical exercises with rest interval).

Collection of information: to obtain the data about progress in training and pulse frequency we conducted full factorial experiment of 2^2 type. The plan of the experiment is given in the table 1.

Table 1.
Matrix of plan of 2^2 for sub-group (5-6 persons) of junior gymnasts

Description of exercise	Variant	X_1 Scope in elements, quantity	X_2 Time of rest, sec.
Rings, horizontal bar, parallel bars	1	30	60
	2	50	60
	3	30	110
	4	50	110
Gymnastic horse	1	70	50
	2	100	50
	3	70	80
	4	100	80
Spring jump	1	10	40
	2	20	40
	3	10	60
	4	20	60
Acrobatics	1	60	60
	2	90	60
	3	60	90
	4	90	90

Table 2
Results of training process's dependence on dynamic of puls in a session

№	X, HBR	Y, points for fulfillment of exercise	Values of function	
			Logistic	Parabol of the second order
1	128.234	0.862	1.111	0.834
2	130.102	0.985	1.101	0.926
3	131.969	0.971	1.092	1.004
4	133.,837	1.033	1.082	1.068
5	135.705	1.058	1.071	1.118
6	137.573	1.099	1.060	1.155
7	139.440	1.139	1.049	1.177
8	141.308	1.212	1.037	1.186
9	143.176	1.254	1.025	1.181
10	145.044	1.220	1.013	1.162
11	146.911	1.168	1.000	1.129
12	148.779	1.100	0.987	1.082
13	150.647	1.007	0.974	1.022
14	152.515	0.930	0.960	0.947

Table 3
Mathematical analysis of functions

Parameters	Logistic function	Parabol of the second order
Bending point	-161.148	
Min Y	0.655	
Max Y	1.149	1.186
Min X	200.241	
Max X	119.239	141.551
Error of regression	0.126	0.030
Coefficient R	0.499	0.989
F-criterion	0.460	0.001

In every session we registered change of training results and pulse frequency from one attempt to the other.

Storage of information

Data base (gymnastics.DBF) was created for storage and processing of results. The results are stored in a file. With the help of a base EXE file (DBGMN.EXE) we enlarged the data base and created text files for analysis of results. Information was stored on a flash drive in a catalogue under the name of a gymnast (for example C:\STEPANOV).

Ideology of processing of information

The conducted research permitted to determine effectiveness and reliability of pans of factorial experiment of 2^2 type in assessment of different working modes' results and their influence on the functional state and junior gymnasts' ability to master movement.

Analysis of the change of training results and pulse frequency in every plan of training showed that both processes can be described with models of increment

$$Y = [A/1+10(^{am+bx})] + C \quad (1)$$

where Y (heart rate / level of mastering) – result of function depending on quantity of attempts (x).

Coefficients of regression equations of logistic function substantially change depending on modes of exercises' fulfillment and rest.

This dependence can be described by equations 2-5:

$$A = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 \quad (2)$$
$$C = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 \quad (3)$$
$$am = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 \quad (4)$$
$$b = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 \quad (5)$$

where A, C, *am, b* coefficient of logistic function, x_1 - scope of movements in training, x_2 - interval of rest.

It was found that there exists a non-linear dependence between the change in training process and pulse frequency of type:

$$Y = a + b_1x + b_2x^2 \quad (6)$$

where Y - result of training, x - pulse frequency.

At the point $x = -b_1/2b_2$ we observed a maximal level of result and pulse frequency approach to border between work oriented on mastering and development of endurance.

Processing of information

Algorithm of analysis of research results:

1. Calculation of logistic function's parameters
2. Calculation of MINMAX characteristics of logistic functions (Khudolii, 2005).
3. For determination of experimental and theoretical points' similarity we carried out dispersion analysis. Errors calculated as well as coefficient of in-class correlation and Fisher's criterion.
4. For determination of coefficients of logistic function depending of working mode we used algorithm of analysis of full factorial experiment.
5. Calculation experiment (1). A mass of training results and pulse frequencies from attempt to attempt is formed. Elements of masses are calculated on the basis of logistic function's analysis.

Parameters of equation: A, a, b, C are calculated on the base of solution of equations 2-5.

Regression coefficients were received as a result of analysis of data of full factorial experiment (FFE) of 2^2 type.

Results of calculation experiment are presented in the form of logistic function and parabola of the second order.

6. Calculation experiment (2). Distribution of training results Yres = Yk - Yp is analyzed with parameters of work on apparatuses as well as with pulse frequencies, correlation of mastering work, development of endurance and repetitions. Where Yk – is the final result, Yp – initial result.

Interpretation of results

1. Calculation of logistic function's coefficients for dynamics of heart beat rate (HBR) in every experience of a plan (see table 1).
2. Results of the analysis show that

logistic function describes results of HBR dynamic (r_1=0.843; r_2=0.756; r_3=0,623; r_4=0.921; p<0.05) rather exactly. Verification of logistic function's coefficients witnesses that between experimental and theoretical values there is no statistically significant difference (p<0.001).

3. Calculation of regression coefficients for specifying of logistic function's parameters depending on the offered working mode for HBR dynamic.

4. Calculation of coefficients of logistic function for dynamics in exercise's fulfillment in every item of the research plan (see table 1).

5. Results of analysis witness that logistic function describes exercise's assessment dynamic quite exactly (r_1=0.974; r_2=0.746; r_3=0.786; r_4=0.935; p<0.05). Verification of logistic function's coefficients witnesses that between experimental and theoretical values there is no statistically significant difference (p<0.001).

6. Calculation of regression coefficients for specifying of logistic function's parameters depending on the offered working mode for dynamics of exercise fulfillment.

6. Analysis of the data distribution witnesses that training results can be considered, to certain extent, to be normally distributed. Optimal increment step is value, equal to X+s. Where, X – is mean arithmetic, s – standard deviation (see fig.1).

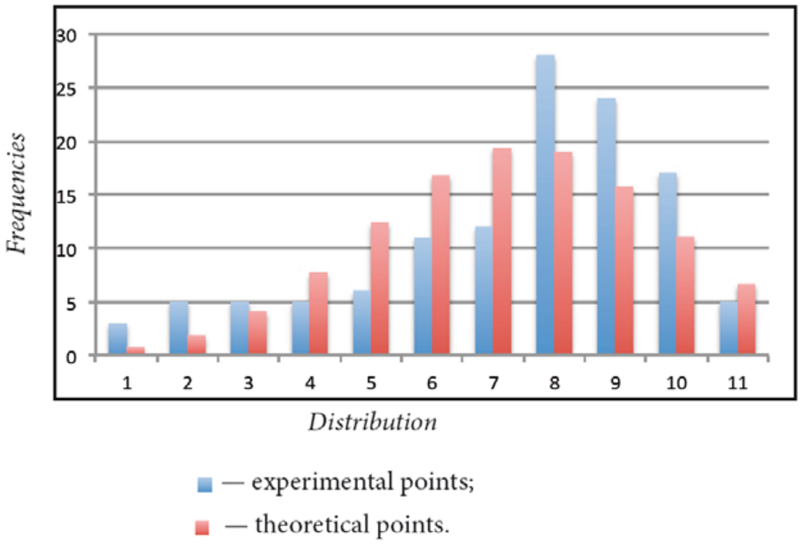

*Figure 1***.** Distribution of points' for junior gymnasts' fulfillment of exercises increments as per results of calculation experiment .

7. Mathematical analysis of logistic function and parabola of the second order shows that equations of parabola of the second order describe results of calculation experiment better. In this case regression error is lower and reliability is higher (see tables 2, 3).

$$Y = 0.716 / 1 + 10^{(-2,936+0,018\,x)} + 0.538 \quad (7)$$

$$Y = -38.593 + 0.562\,x - 0.002\,x^2 \quad (8)$$

HBR of 141 bpm can be regarded as a border between work, oriented on endurance and training.

8. The conducted regression analysis showed that increment of points for exercise's fulfillment statistically significantly depends on the following groups of indicators:

- *Level of fitness:* maximal mark is (x_1), efficiency (x_2), maximal HBR (x_3); quantity of attempts for reaching of optimal HBR is (x_4) (multiple coefficient of determination DM=0.978; p<0.001):

$$Y=3.968+0.216x_1+0.649x_2-0.034x_3+0.027x_4 \quad (9)$$

- *Organization of loads:* volume in elements is (x_1), time of rest (x_2), quantity of attempts (x_3), quantity of elements in attempt (x_4) (multiple coefficient of determination DM=0.972; p<0.001):

$$Y=-3.217+0.066x_1+0.035x_2+0.053x_3-1.523x_4 \quad (10)$$

- *Orientation of training:* time assigned for mastering % (x_1), time assigned for development of endurance, % (x_2), time for repetitions, % (x_3), volume in elements (x_4) (multiple coefficient of determination DM=0.924; p<0.001):

$$Y=-5.103+0.076x_1+0.072x_2+0.081x_3-0.026x_4 \quad (11)$$

Thus, the offered algorithm of computer simulation of training process permits to receive new information about influence of fitness level, load, organization and trainings' orientation on effectiveness of formation of child and adolescent motor skills.

DISCUSSION

In this work we used methodological approach to create applied program in the field of physical education and sport (Hong, 2013), worked out the software for taking decisions in planning of trainings (Wu, 2013), simulation in the field of bio-mechanics (Merala & Piziali, 1996; Kirk, 1999; Takei, Blucker, Nohara, & Yamashita, 2000; Boloban, Litvinenko, & Otsupok, 2012; Jensen, Scott, Krustrup, & Mohr, 2013; Bhatia, Davis, & Shamas-Brandt, 2015), assessment of pupils' functional state (Wright, 1999; Lucenko, 2003; Rink, Jones, Kirby, Mitchell, & Doutis, 2007).

The results, received by us, supplement the data of other researchers and agree with them. Griggs & McGregor (2011) recommends to use creative approach to training of gymnastic exercises. Hiley, Wangler, & Predescu (2009) recommends to apply computer imitation models to increase the quality of front arms' fulfillment, which permits to optimize methodological approach to training. Irwin, Hanton, & Kerwin. (2005) stresses the demand to understand main mechanisms of motor skill formation. The offered approaches concerning simulation of training process of junior gymnasts also agree with results of other researchers. Adams, Cintas, & Llabrés (2005), Correa, Grima, & Tort-Martorell (2009, 2012) say that in factorial experiment expected effect can not be achieved always with neutralization of unknown factors' influence. That is why the authors offer to combine proper level of protection from unknown factors with minimal quantity of factors and their levels. Lundkvist & Vanhatalo (2014) in their research of dynamic processes attract attention to inadmissibility of errors in observations, the data of which are used for building of factorial experiments' plans.

The received data are confirmed by researches of Ivashchenko (1988), who showed that fulfillment of exercises on apparatuses by junior girl-gymnasts in HBR zone within 140-160 bpm results in tiredness. In its turn, it results in worsening of exercise's fulfillment quality by 0.3-0.6 points. Fulfillment of exercises in HBR zone within 120-135 bpm does not worsen the quality of exercise's fulfillment. Fulfillment of exercises in HBR zone within 100-119 bpm facilitates increasing of quality by 0.3-0.4 points. Also, the purpose of calculation and usage of control system of complex assessment of gymnast fitness (Zaporozhanov, Kochanowicz, & Kochanowicz, 2014; Zaporozhanov, Borachinski, & Nosko, 2015) have been proved.

Our results expand and supplement the data of Khudolii and Karpunec' (2001), Khudolii and Ivashchenko (2004), and Khudolii (2005) about effectiveness of application of factorial experiments' plans in studying of training process's effectiveness and in development of children's and adolescents' motor skills. In opinion of Wang, Karns and Meredith (2003) and García-Moya, Moreno, and Jiménez-Iglesias (2012) application of factorial experiment plan in research involving children and adolescents, facilitates increase of their indicators. Validity of application of 2^k full factorial experiment is also proved by data of Correa, Grima, & Tort-Martorell (2009).

Results of our research witness that in the offered matrices of factorial experiment plans, the chosen step of factors' varying is sufficient for studying of influence of different modes of physical exercises' fulfillment on progressing of strength and effectiveness of children's and adolescents' training (see table 1).

Novel is the algorithm of informational provisioning of children's and adolescents' training to motor skills, which differs from commonly known approaches (see fig.2).

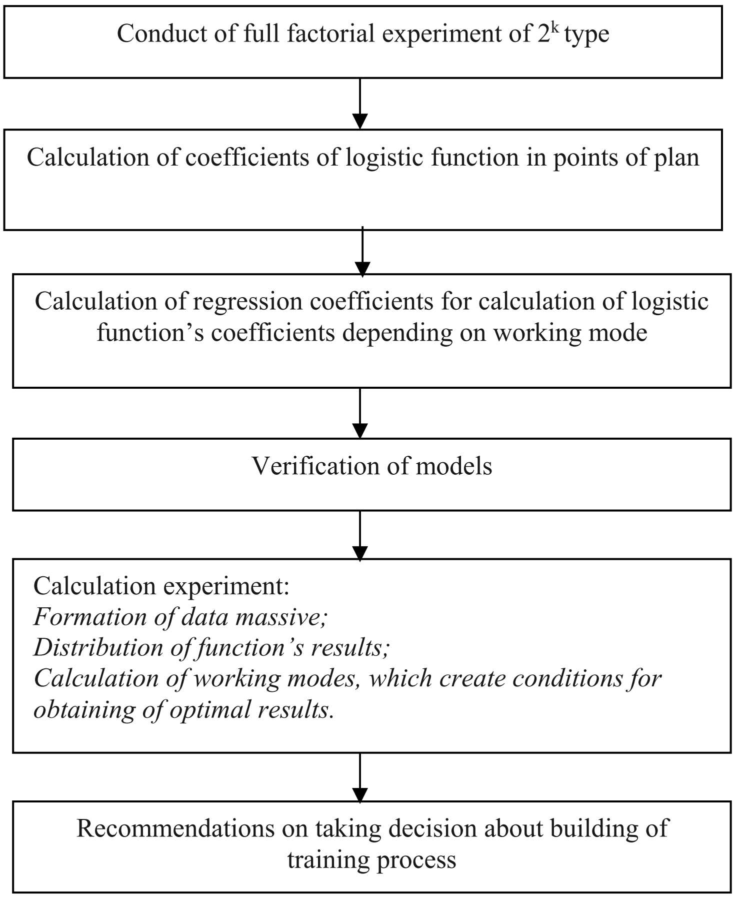

*Figure 2***.** Schema of algorithm of informational provisioning for training process of children's

and adolescents' motor actions.

In distinction from applied programs of complex monitoring of 1-11 forms' pupils' physical condition, considering physical condition, functional and physical fitness, depending on peculiarities of schoolchildren mass-height indicators (Shandrigos', 2000, 2002; Vovk, 2002; Borysova & Vlasyuk, 2013) the algorithm offered by us is based on computer simulation of children's and adolescents' training process.

CONCLUSIONS

The worked out algorithm of computer simulation of modes of gymnastic exercise fulfillment permitted to determine that increments in points of exercise fulfillment statistically confidently depends on the following groups of indicators:

- *Level of fitness:* maximal mark is (x_1), efficiency (x_2), maximal HBR (x_3); quantity of attempts for reaching of optimal HBR is (x_4) (multiple coefficient of determination DM=0.978; p<0.001);
- *Organization of loads:* volume in elements is (x_1), time of rest (x_2), quantity of attempts (x_3), quantity of elements in attempt (x_4) (multiple coefficient of determination DM=0.972; p<0.001);
- *Orientation of training:* time assigned for mastering % (x_1), time assigned for development of endurance, % (x_2), time for repetitions, % (x_3), volume in elements (x_4) (multiple coefficient of determination DM=0.924; p<0.001).

On the base of this algorithm we created a pilot complex of programs of informational provisioning of children's and adolescents' training in motor actions as well as in development of their motor skills.

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