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Research Article

THE EFFECTIVENESS OF CHOSEN TRAINING MEANS IN THE DEVELOPMENT OF ENDURANCE IN YOUTH SWIMMERS

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ABSTRACT

The main objective of the work was to present the practical application of a mathematical model to optimize sports training. From empirical data, collected during an experiment a mathematical model of sports training for young swimmers was created. The effectiveness of particular training means on sport results was evaluated. The research was conducted on a group of 20 youth swimmers aged 14±0,5 years, with an average body mass of 50,73±7,39 kg and body height of 164,2±8,12 cm respectively. The swimmers presented a high, national level of sports performance. The research allowed to draw theoretical and practical conclusions regarding the application of the mathematical model in sports training.

Key words: *swimming, training loads, mathematical model.*

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INTRODUCTION

The relationship between the type and intensity of the training stimuli and the reaction of the athlete to those stimuli is one of the most important research objectives in sport sciences.

The complexity of this phenomenon is related to the determination of particular relationships on a set of traits with a highly differentiated character. The application of excessive training loads leads to overtraining and often to injuries, while the use of inadequate training loads does not allow the athlete to reach his full potential (Bompa, 2000; Costill, 1991).

On the basis of current knowledge of sports training, one can assume that the adaptive processes of the athlete are dependent mainly on two factors: type and strength of the training stimuli and the reactiveness of the organism, which is strongly controlled by the genetic makeup. Despite the many attempts to optimize sports training, an algorithm has not been created, which would allow for precise steering of the training process.

Considering the fact, that the human adaptive possibilities are Explorer close to its maximum (Bouchard and Rankinen, 2001; Bułgakowa and Sachnowski, 2000), the most important objective of current competitive sports training is the development of a tool, which would allow for precise application of training loads. At the same time it must be stated that the use of many statistical methods for optimizing sports training, such as correlation coefficients or factor analysis is limited and of little value. Taking this into consideration sport scientists must seek more adequate mathematical and numerical methods for solving the complex problems of sports training (Ryguła and Cholewa, 1999).

The main objective of his work was to evaluate the application of the mathematical model in evaluation of effectives of chosen training means in developing endurance in youth swimmers. The following, specific research questions were created:

1. Does the mathematical model created upon experimental data allow to estimate the influence of particular training means on the level of specific endurance in youth swimmers?

2. Which of the applied training means have the greatest effect on improvement of specific endurance in swimming?

MATERIAL AND METHODS

To reach the major objective of the work a pedagogical experiment was conducted. The empirical data from this experiment allowed to create the mathematical model of sports training, which was later verified. The research material included 20 national youth level swimmers. Their basic characteristics are presented in table 1.

Table 1. *Statistical characteristic of considered variables in the tested athletes before the beginning of the experiment.*

Variables	$\bar{x}$	S	A_s	Ku	V
Body height [cm]	163,1	3,28	1,32	1,98	4,15
Body mass [kg]	50,64	7,65	-1,05	2,54	15,10
Length of upper limbs [cm]	72,51	3,85	0,85	2,07	4,89
Length o flower limbs [cm]	78,16	3,89	1,12	2,42	4,15
VO_{2max} [L/min]	3,05	0,48	-1,54	2,78	15,45
Peak power [W/kg]	9,11	1,67	1,18	2,08	15,98
Vital lung capacity [cm^3]	30255	241,57	1,99	-1,75	7,58

$\bar{x}$ - arithmetic mean, S – standard deviation, A_s – index of asymmetry, Ku - kurtosis, V - variability.

During the experiment the tested youth athletes conducted 5 training session in the swimming pool (1,5h) and two on land sessions in the gym (1,5h).

A simplified catalog of training means was created, which allowed to register the quantitative and qualitative aspects of each training session. The volume of work was measured by the time of particular exercises, while intensity was evaluated through a scale of intensity. There were 5 levels of intensity in this scale, which were based mainly on heart rate and time of the exercise. These levels are presented below:

Level 1. Aerobic, low intensity (HR≤140bts/min).

Level 2. Aerobic, moderate to high intensity (HR=150-165bts/min).

Level 3. Above AT, high intensity (HR=165-175bts/min).

Level 4. Anaerobic glycolytic, submax intensity, (HR=180-200bts/min).

Level 5. Anaerobic phosphagen, max intensity.

During the experiment the following training means were applied, which played the role of decision variables:

1. General fitness exercises: on land agility and strength exercises (int.4).

2. Continuous distance runs, Farelek, team sports (int.3).

Training means applied in the water:

3. Speed training: distances up to 25 m., starts, turns, (full recovery rest periods) (int.5).

4. Speer endurance, lactate tolerance: distances between 25 and 50 m., swimming exercises with the use of only upper or lower limbs or in combination. (full recovery rest periods) (int.4).

5. Exercises above AT: distances between 100 – 200 m, swimming exercises with the use of only upper or lower limbs or in combination. Incomplete recovery during rest periods (int.3).

6. Aerobic endurance exercises, distances between 400 and 800 m, Incomplete recovery during rest periods (int.2).

7. Slow pace continuous swimming. (int.1).

8. Exercises directed at the improvement of swimming technique (int.2).

9. Exercises directed At teaching swimming technique (int.1).

10. Competition.

The training loads were changed during monthly mesocycles, and both volume and intensity were modified. The training loads were chosen randomly. All of the chosen training means had their limitations.

For the construction of the mathematical model, as a quality indicator the result at 800 m freestyle was chosen, which was converted to points according to swimming tables used by FINA.

During the experiment the following variables were measured (state variables):

X1 – body height [cm], X2 – body mass [kg], X3 – length o flower limbs [cm], X4 – length of upper limbs [cm], X5 – aerobic capacity (VO_{2max}) [l/kg * min], X6 – anaerobic power, evaluated by the Wingate test [W/kg], X7 – vital capacity [cm^3].

Decision variables: total time of particular training means in consecutive training cycles according to the catalog created. The evaluations were conducted after each monthly mesocycle.

The construction of the mathematical model for swim training

The value of each state variable (sport results) at the end of a particular training cycle is a function of the general state of the athlete, described through state variables at the beginning of that cycle and the accompanied training means (steering variables) with their volume, intensity and type of stimulus. This can be presented mathematically as follows:

Where l is the number of the training cycle, l=0,...,N-1.

For further calculations it was assumed that there were an n number of state variables and an m number of applied training means. Next the following description of the vector for state variables was created $X(t)=(x_1(t),...,xn(t))^T$, and for the vector of steering variables $U(t)=(u_1(t),...,um(t)^T$. The upper index ^{T} relates to the transposition of the matrix vector.

The sports training model for youth swimmers was described by the following system of equations:

$$\frac{dx_i}{dt} = \sum_{j=1}^{n} a_{ij} x_j + \sum_{j=1}^{n}\sum_{k=1}^{m} b^i_{jk} x_j u_k + \sum_{j=1}^{m} c_{ij} u_j + d_i + h_i(t, U) \quad i=1,...,n$$

Where:
x_i is i-state variable, i=1,...,n,

u_j the application of j- particular training means j=1,...,m.,

$u_j \in [0,1]$, 0 - none, 1 – maximal possible effectiveness of j- that particular training means.

In the construction of the model the methods described by Pearl (2002) and Ryguła (2000) were used. The model of the considered phenomena ended up in the form of 7 differentiation equations. To determine the precision of the model, fit coefficients were calculated, which are a multidimensional appropriate of the relative error.

RESULTS

Table 2. *Coefficients of model fit for particular equations.*

Equation for variable	δ_i [%]	Equation for variable	δ_i [%]
X1	5.5	X5	4.9
X2	4.0	X6	1.2
X3	6.8	X7	4.4
X4	5.5	--	--

Table 3. *The effects of steering variables on changes in state variables.*

State	Steering variables									
Variables	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
X1	-140.61	**72.98**	**53.52**	-44.56	23.69	18.42	-16.51	-44.71	-21.72	**65.15**
X2	-584.41	-87.40	-8.17	82.09	-1.13	116.30	242.39	378.89	-54.81	8.50
X3	14.07	11.25	-2.80	-17.74	-1.74	0.52	-2.52	-8.87	3.98	-2.86
X4	-12.78	-2.02	-4.63	-2.63	-0.54	-0.91	5.36	14.10	-2.72	4.68
X5	7.28	-5.98	-2.70	2.28	-0.50	-1.05	1.44	5.96	-2.00	-3.11
X6	8.63	-2.81	3.32	4.93	1.78	3.79	0.97	-7.48	-2.79	-5.94
X7	-604.73	137.47	722.07	294.65	171.21	486.91	45.79	-1004.7	25.41	-94.86

Table 4. *The effects of state and steering variables on the sport result evaluated by 800m time converted to points.*

State Variables	Steering variables									
	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
X1	-2.73	-7.64	-1.93	2.86	3.17	-0.16	16.20	32.45	-9.10	-7.70
X2	12.56	6.39	-0.72	-0.35	-4.56	-4.69	-12.49	-25.41	6.76	2.38
X3	-40.89	-8.76	-13.42	15.73	10.24	10.05	39.08	31.43	-32.40	-31.27
X4	4.00	6.55	7.10	11.23	-0.40	4.17	5.76	-10.88	7.22	6.00
X5	64.69	-123.88	-74.07	18.43	-31.82	-21.44	14.01	147.70	20.25	-21.51
X6	35.62	30.05	27.07	14.28	10.91	3.86	-12.11	-53.77	7.68	-28.13
X7	57.37	23.47	0.75	-16.39	-9.85	-8.39	-29.02	-73.67	18.38	20.94

DISCUSSION

Scientists and coaches all over the Word are constantly searching for tools that would enable to determine the relationships between applied training stimulus and the adaptive changes, which are related to sport results. Many suggest the use of mathematical methods to describe these relationships. Both theoretical assumptions (Kanister and Calvert, 1975; Calvert et al. 1976) and practical verification of calculated models (Bondarczuk and Szurepow, 1990; Gordon et al., 1973; Morton et al., 1990) indicate a possibility of use in optimizing sports training. The conducted research confirms this hypothesis. On the basis of empirical data collected from the experiment a mathematical model for swim training was created. The obtained fit coefficients are very small what indicates a high precision of the model.

The created in this work model of sports training allows for the determination of result improvement in relation to the applied training means. This was confirmed by Banister et al. (1999), who calculated the optimal relationship between particular components of training loads in attempt to maximize sport results. Their findings are similar to those of other researchers (Hooper et al., 1998; Shepley et al., 1992) indicating that a rise in intensity and a concomitant decrease in volume brings an improvement in sport results. Taking this into consideration, it can be stated that a significant reduction of work volume during the precompetitive period allows to avoid the accumulation of fatigue and possible overtraining (Bannister et al., 1999).

In most of the papers presented above the mathematical model was applied in a very general matter, limiting the steering process to simple relationships between volume and intensity as well as exercise time and recovery time (Busso et al., 1994; Clarke and Ricci, 2009). Our research with the use of the mathematical model included quality indicators, evaluating the influence of particular training means on performance. From the considered training means in our experiment the following variables (U2, U3, U10) had the greatest impact on swimming results at 800 m.

The variable U2 includes land exercises which are directed at the development of aerobic power. Results of experimental data confirm favourable conditions for development of aerobic processes during maturity or even as early as the beginning of elementary school.

According to most specialists, the development of aerobic endurance for swimming should begin between the age of 8 and 10, but not later than 12 (Rowland, 2004). Data presented by

Malina and Bouchard (1991) indicates that children between the age of 8 and 12 are well adapted for long continuous swim exercises (10-30min) with moderate intensity, or short ones (3-10s), even performed under conditions of incomplete rest intervals with max intensity. The predispositions of children at this age for aerobic exercise are a consequence of very proportional body structure and well developed cardiovascular and pulmonary systems (Martens, 1999). The energy cost of swimming 800m is covered in 80-90% with the resynthesis of ATP through aerobic mechanisms (Costill, 1992; Troup et al., 1990; 1991). Considering the exercise metabolism of swim competition at 800m one must assume that training should reflect these demands. The application of aerobic exercises should significantly improve sport results at this distance.

The variable U3 includes exercises that develop speed abilities. Speed is perhaps best developed in very young athletes because of the high neuromuscular efficiency already at the age of 7-8 (Rowland, 2004; Zając, 2005). The best period of developing speed abilities seems to include the time span, where speed is developed independently of strength. This may last from the age of 7 up to maturity, around the age of 13 (Bompa, 2000; Rowland, 2004).

The greatest improvements in movement frequency are observed in children between the age of 7-9 and 12-13, while whole body speed is most improved between the ages of 10-12.

Children are also well adapted to speed exercises. The high liability of the neuromuscular system and the great efficiency of other major physiological functions of the body at this age allow children to perform many repetitions, with high intensity with very fast post exercise recovery. The application of speed exercises in youth athletes seems fully justified (Dintiman et al., 1997). Variable U10 includes competitions. The competition method of improving sport results is very popular among many sport disciplines and its effectiveness has been confirmed many times. Competitions at distances shorter and longer than the main event are the most specific means of sports training in swimming, especially that the movement structure (coordination) is identical to that during major competition. The application of the competitive method of sports training allows to collect data regarding the level of motor development and technique, what helps significantly in modification of training loads in order to achieve peak performance during a particular season (Maglischo, 2003; Platonow, 2004; Zajac, 2005). On the other hand one must bear in mind that excessive competitions for youth athletes are often the cause of mental stress and overtraining. Despite the high effectiveness of the competitive method of sports training, it must be introduced gradually into youth programs, and the overuse of this very strong stimulus in youth athletes diminishes its effectiveness in performance improvement during later stages of the career.

Many coaches apply similar training means and trading loads to youth athletes as to adults what brings fantastic results in particular age categories, yet leads to physical and mental burn-out of young swimmers. Because of that, many talented athletes pull out of competitive swimming before reaching their full potential. It must be reminded that the use of very intensive and very specific training means early in the career, diminishes their effectiveness in stimulating adaptive changes in more advanced athletes, what significantly slows down the progress in motor development and performance improvement.

Several authors indicate that the application of very intensive training means in youth athletes in swimming for a prolonged time diminishes their effectiveness in successive mesocycles and almost excludes the positive influence of low intensity exercise of general fitness (Colwin, 2003; Hannula and Thornton, 2001). In our research the negative influence of variable U1 on sport results indicates that the effectiveness of general fitness exercises has been exploited and more specific training means must be applied.

During competitive sports training, proper proportions must be maintained between the applied training means, which consist the main stimulus for adaptive changes in the athlete's body. The structure of the training means and loads should vary, depending on the goal, age, experience, sports level, training period and adaptive possibilities of athletes. The determination of these relationships significantly influence sport results (Hellard et al., 2002). Solving this problem requires not only basic coaching knowledge, but also advanced tools for controlling the training process. The mathematical model of sports training can meet the demands of such a tool.

CONCLUSIONS

The empirical data and the conducted analysis allow for the following conclusions, which can have practical implications for coaches:

- The construction of a mathematical model of sport training allows to determine the effectiveness of particular training means.

- The greatest influence on endurance in youth swimmers are achieved by aerobic land exercises, speed exercises performed in the water and competitions.

- On the basis of calculated fit coefficients, which are a multidimensional appropriate of the relative error it can be stated that the constructed model has a significant practical application.

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