СОФИЙСКИ УНИВЕРСИТЕТ „СВ. КЛИМЕНТ ОХРИДСКИ"

SPORTS DEPARTMENT
INDIVIDUAL SPORTS AND RECREATION SECTOR

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INNOVATIVE ADAPTIVE MODELS FOR SPECIALISED RUNNING ENDURANCE IN THE EDUCATIONAL AND SPORTS PROCESS

ABSTRACT

Sofia, 2023

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for the award of scientific degree
"DOCTOR OF SCIENCE"
in professional field - 1.3. Pedagogy of Education in...
(METHODOLOGY OF PHYSICAL EDUCATION AND SPORT)

Sofia, 2023

The dissertation was discussed at an internal defense and proposed for official defense at a meeting of the "Individual Sports and Recreation" Sector at the Sports Department of Sofia University "St. Kliment Ohridski"

The content of the work has a total volume of 288 pages, illustrated with 32 tables and 21 figures.

The bibliography covers: 148 titles in Cyrillic, 50 titles in Latin, 3 Internet sources.

The public defense of the dissertation will take place at 06.06.2023
from 11:30 am

INTRODUCTION

Physical education, as part of a person's physical procurement, is defined as an organized pedagogical process that primarily stimulates health and the development of vital motor habits.

In this sense, the phenomenon of sports has established itself as one of the principal instruments for the refinement of the human biological system and a field of complex scientific research of its adequate existence under the changing conditions of the external environment.

In this regard, sports turns out to be one of the most integrative fields for studying the adaptive processes of the human organism due to the fact that adaptation under the conditions of sports activities is a basic category which the main problems of sports development are subjected to.

The key point, around which the thesis of the present work is centred, is adaptation. Its broad conceptual content will focus on the underlying processes and patterns in building specialized running endurance, based on research and experimentation in the training of intermediate middle-distance runners and soccer players.

It is expected the results and analyses of this study to enable sports pedagogues to expand, enrich and specify the methods and tools for building and refining specialised endurance.

The paper has been discussed and debated extensively with track and field and soccer colleagues, tutors and coaches, to whom we express our gratitude.

I. RELEVANCE OF THE ISSUE

On the grounds of a comprehensive literature review and the available practical experience so far regarding changes cropping up in the adaptive processes under the effect of the running loads, it is odd that studies on the building of specialised endurance is rather more concerned with advanced athletes than with beginner or intermediate middle-distance runners.

On the other hand, the physical fitness training of soccer players is increasingly being "confined" to one part of the pitch for short and low-intensity running exercises.

The idea of combining research based on this category of middle-distance runners and soccer players in the dissertation work is also complemented by the fact that the average annual aerobic running volume, in our opinion and in that of other authors we have quoted, is assumed to be almost identical for both.

One such statement, supported by research, analyses and workload classification models, could be beneficial to soccer professionals in terms of unveiling individual specific work capacity parameters.

I. 1. WORKING HYPOTHESIS

On the basis of the review of the theoretical aspects of the issue under consideration, it is necessary to study and reveal those indicators in the adaptive process of building specialized endurance, which have a pronounced applied effect and can fulfil the role of optimization criteria in sports training. The issue is of particular relevance to the category of athletes we have studied, where an empirical and expert approach is still relied upon, through an analogous transfer to the sports process when it comes to running performance, without taking into account the biological, motor and psychological characteristics of the adaptive processes.

Thus, the main hypotheses developed in this dissertation work are aimed at clarifying issues of adaptive processes when applying running loads:

1. Identifying the overall running potential.
2. Revealing the structure of the current running potential.
3. Determining the training potential of systemic running loads.
4. Justifying the levels of transition from sustainable to unsustainable working adaptation under running loads.
5. Revealing the optimal algorithm of adaptive processes and building endurance running loads for middle-distance runs with intermediate athletes and soccer players.

We believe that by revealing new optimization criteria and innovative models of adaptive development, prerequisites will be established for increasing the athlete's potential in the training process.

II. OBJECTIVE, TASKS, ORGANIZATION AND METHODS OF RESEARCH

II.1. OBJECTIVE OF THE RESEARCH

The aim of the present research is to develop
Innovative adaptation models for specialized running endurance applicable to the training process.

II.2. RESEARCH TASKS

The so-set objective implies fulfilment of the following prime tasks:

- 1. Draw up a retrospective analysis of the overall running potential of the athlete and any changes that occur when building running endurance;
- 2. Develop models of relevance to the common adaptive levels of the specific work capacity;
- 3. Identify innovative models for the adaptation phases of the training process;
- 4. Structure classification models of sports activities - organization, volume, intensity;
- 5. Construct specific applicable models for activities in running fitness training with soccer players.

II.3. SUBJECT, OBJECT, CONTINGENT AND ORGANIZATION OF RESEARCH

- • **SUBJECT OF THIS RESEARCH** are the processes of adapting the athlete to running endurance loads.
- • **THE OBJECT OF RESEARCH** are the changes in the adaptive capabilities of the athlete and their modelling during the training process under the influence of running loads.

- **CONTINGENT OF RESEARCH** are 87 athletes, of which 37 intermediate middle-distance runners and 50 soccer players.

II.4. METHODS OF RESEARCH

To achieve the goal thus set and fulfil the stemming tasks, we applied the following research methods:

- • Review of scientific and methodological literature. 198 works were thoroughly studied and analysed, of which 148 in Cyrillic and 50 in Latin. Additionally, 3 Internet sources were used.
- Review of sports-pedagogical and medico biological tests, listed in Table 1.

Table 1. Sports and medicobiological tests

Test name	Units of measurement
STANDING LONG JUMP	sec.
VERTICAL JUMP	sec.
STANDING TRIPLE JUMP	sec.
RUNS of 30, 100, 200, 300, 400, 600, 800, 1000, 1500 and 2000 m.	sec/min
10 X 20 m. RUN	sec.
3200 m. RUN	min.
800 m. RUN by stride length and frequency	min/no.
PWC 170 TEST and VO_2 max	mL/kg
WORKOUT AND RECOVERY HEART RATE	sec/unit

- - Mathematical and Statistical Methods

The results obtained were subjected to mathematical and statistical processing, using MATLAB - methodology by methods adapted to sports and pedagogical research by Hadzhiev, N., Brogley, J., Zhelyazkov, C. 1973, Brogley, J. 1977 and 1979.

Variance, correlation, regression and factor analyses were applied.

THE ANALYSIS OF THE RESULTS OBTAINED regarding changes following the applied running loads for specialised endurance is presented in each model of adaptive development, constructed according to its specific indicators.

III. MODELS OF ADAPTIVE DEVELOPMENT BASED ON RESEARCH WITH INTERMEDIATE RUNNERS

The models developed have to provide proper optimization of the applied loads and the means during the adaptive phases of the sports process.

The essence of the models is pre-planning the loads in terms of organisation, volume and intensity, research with specific reliable tests and statistical processing.

Prior to the final presentation in the dissertation work, each model was purposefully applied to the sports process of the research period. The models - methods for calculating the work rate and the degree of application of the running loads - were also tested.

In this regard, the models now have a guaranteed applied value for the overall adaptation process.

After processing and analysing the research results, eight models were developed for middle-distance runners, revealing the adaptation processes in building specialised endurance through running loads. and two other for soccer players, Methods and models, together with specific research and analysis, for evaluating the critical levels of adaptation in training, were applied therewith.

For middle-distance runners:

1. Model for distributing the volume and intensity of running loads.

2. Model of the multiparametric structure of specific physical capacity

3. Model for organizing the training loads in a special preparatory and pre-competition mesocycle

4. Pulsometric model of the adaptive process

5. Model for setting the critical speed and its transformation into zonal range

6. Model for the application of specific loads for building running strength

7. Experimental model of adaptive development within the macrostructure of training

8. Classification models of training loads

The adaptive changes at critical levels of running endurance with soccer players were developed on the grounds of the aerobic profile of the game and boil down to:

- **1. Model of specific work capacity with soccer players**
- **2. Model of classification of running loads, with volume, intensity and assessment of adaptive levels**
-

III.1. MODEL FOR ALLOCATING VOLUME AND INTENSITY OF RUNNING LOADS

The model reveals the dynamics of running performance, intensity and allocation of running strength loads for the annual training cycle with two-cycle and single-cycle scheduling in the three main aerobic regimes - Figs. 1, 2, 3 and 4.

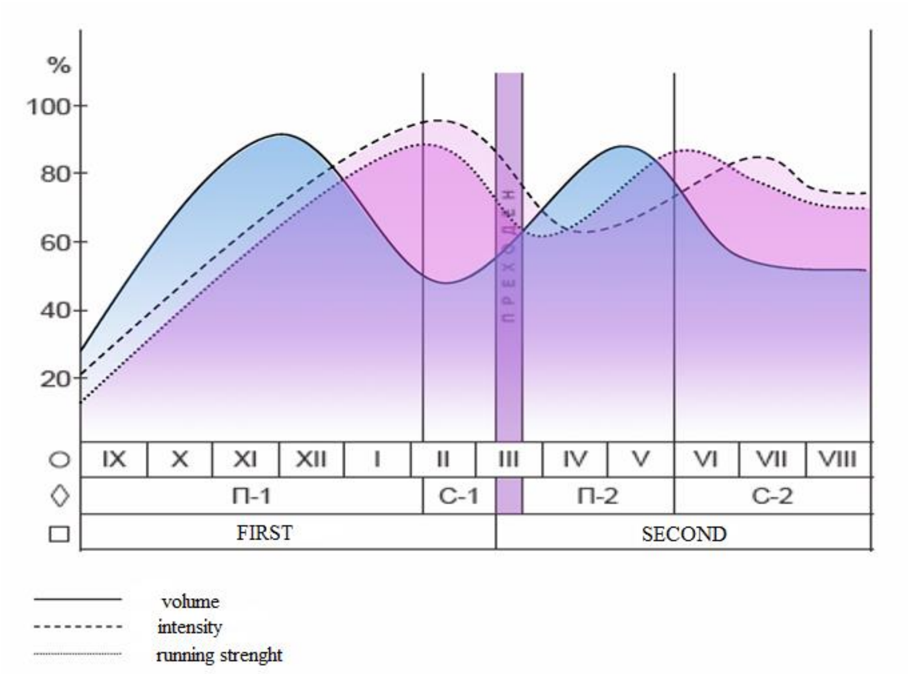


Fig. 1. Model of dynamics - volume, intensity and running strength in two-cycle training

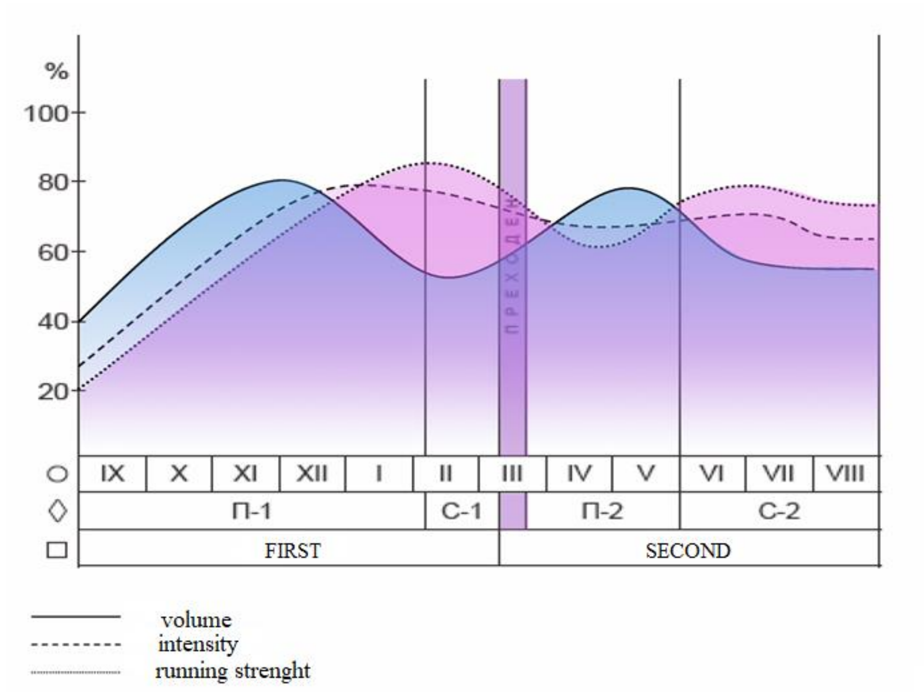


Fig. 2. Model of dynamics and load in aerobic, mixed and anaerobic modes in two-cycle training

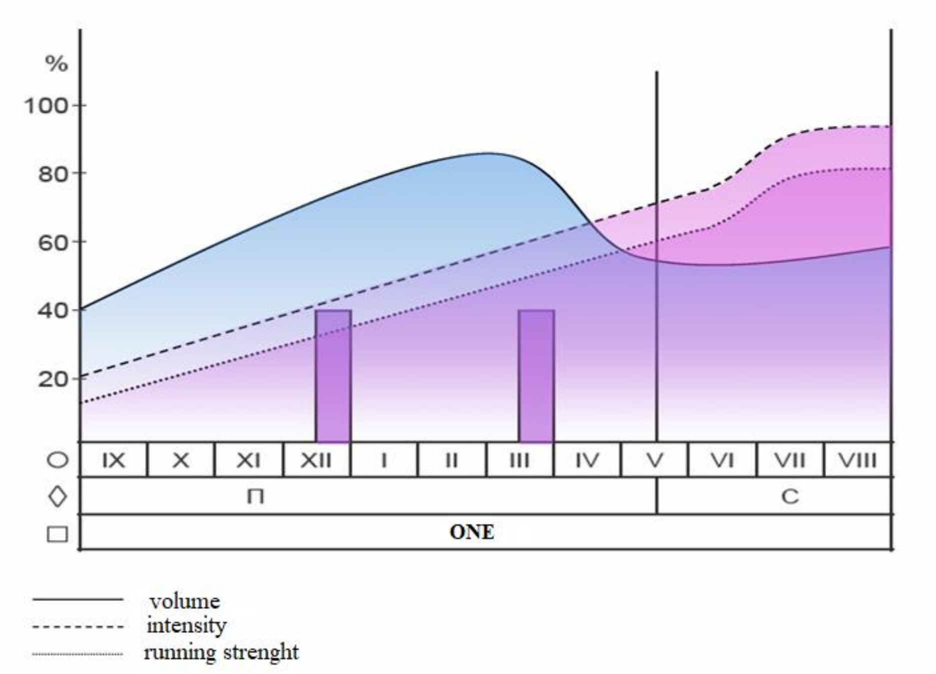


Fig. 3. Model of dynamics - volume, intensity and running power in single-cycle training

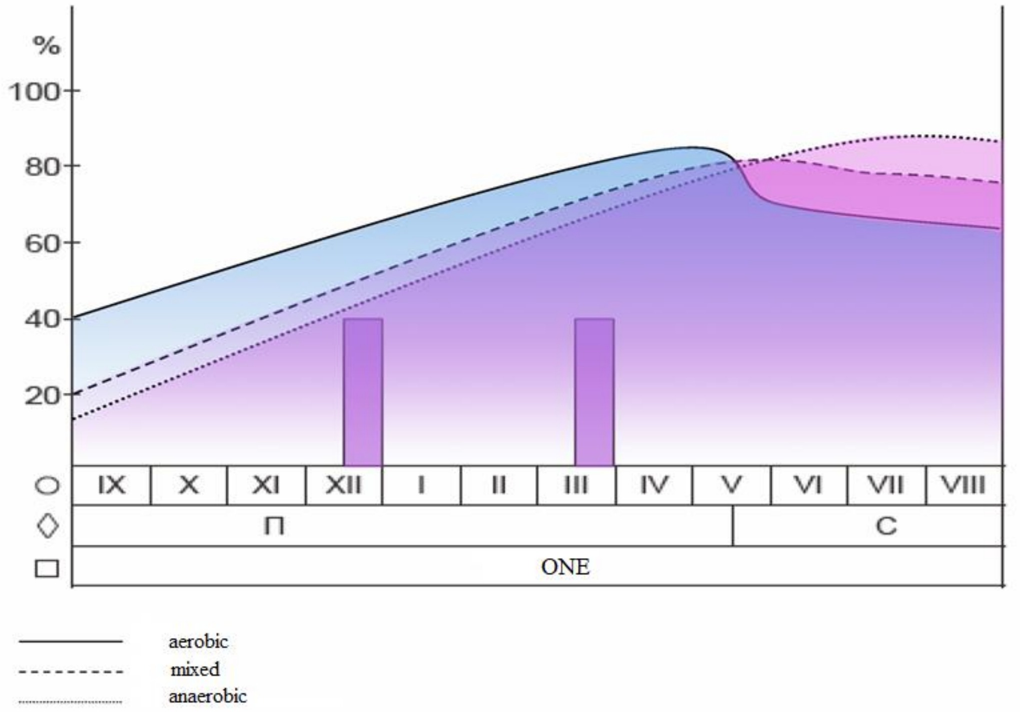
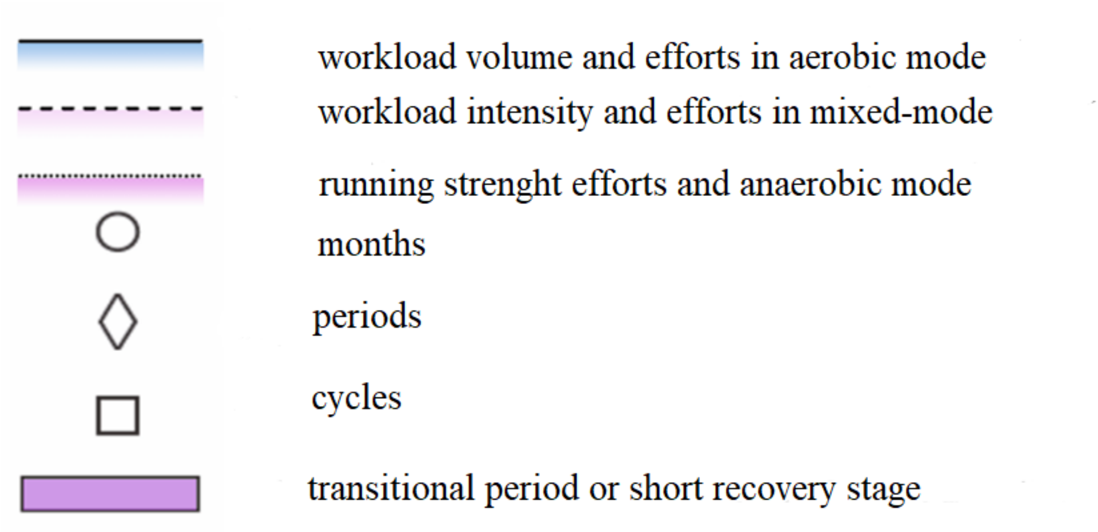


Fig. 4. Model of load dynamics in aerobic, mixed and anaerobic modes during single-cycle training

COMMENTS ON THE GRAPHIC MODELS:



The main scope of the presented graphical models and their structures are the principles expressing the dynamics of sports loads, the quantitative importance for the composition and organization of programming of the most essential parameters of the content of the elements of the sports process.

The model also offers regression capabilities to calculate predicted outcomes at the running distances used, which essentially appear to be the main criteria for adaptive modelling to the outcome of the ultimate sport.

Based on the total amount of running volume and intensity applied during the study period, the model provides principle maximum load readings during different training periods according to the main aerobic modes for this category of athletes.

III.2. MODEL OF THE MULTIPARAMETRIC STRUCTURE OF THE SPECIFIC PHYSICAL WORK CAPACITY

The present model reveals the optimal physical work capacity parameters that are key to optimizing adaptive processes in specific endurance performance in the 800 m run for intermediate runners.

The correlation-factor structure of performance was investigated, which identifies the key indicators and factors determining the level of sports performance.

Of significance for the 800 m base run results are the running distances of 100 m r = 0.81, 300 m and 400 m r = 0.58, as well as the indicators of the running speed r = 0.70, functional status assessment r = 0.69, maximal oxygen consumption r = 0.56, recovery time r = 0.56 and VO_2 max r = 0.53, which are presented in Fig. 5.

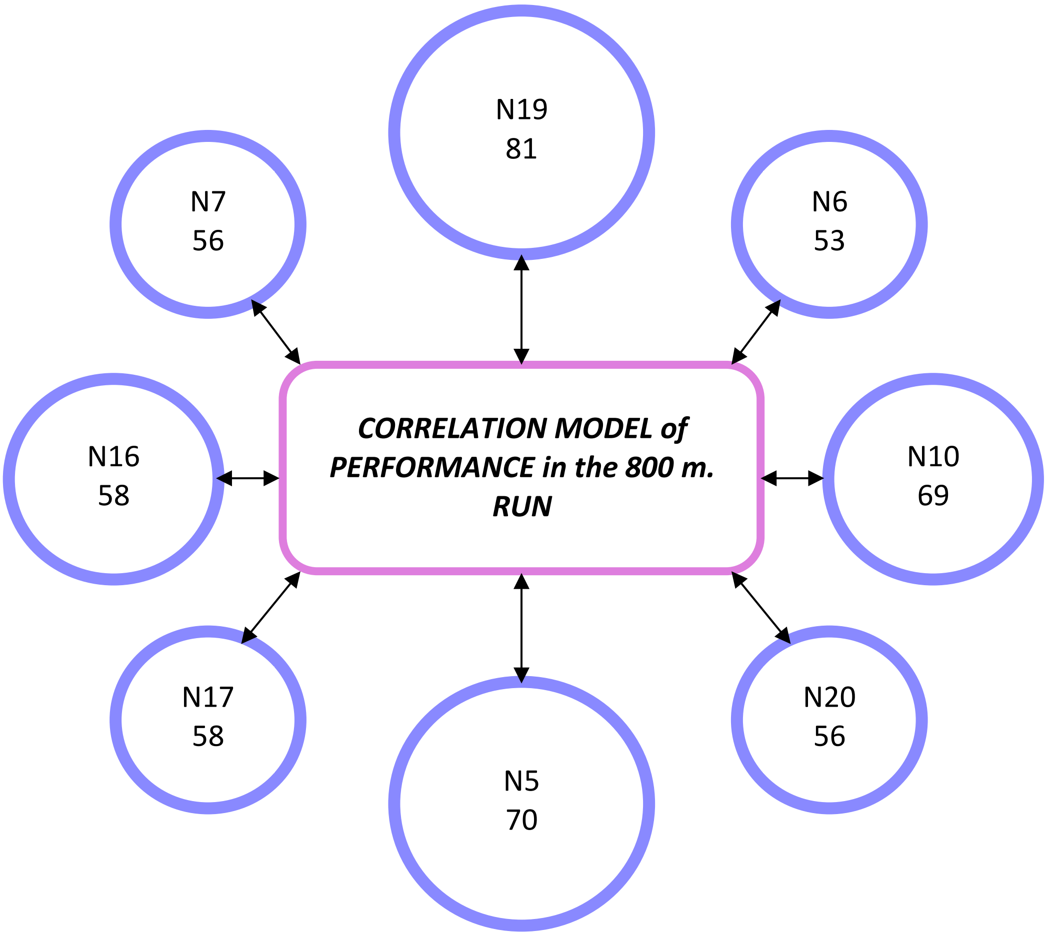


Fig. 5 Model of performance in the 800 m run

In order to clarify more accurately the possibilities for modelling the adaptive processes according to the regularities we are interested in, especially in their complex evaluation, the factor structure of the 800 m base run result is shown in Fig. 6.

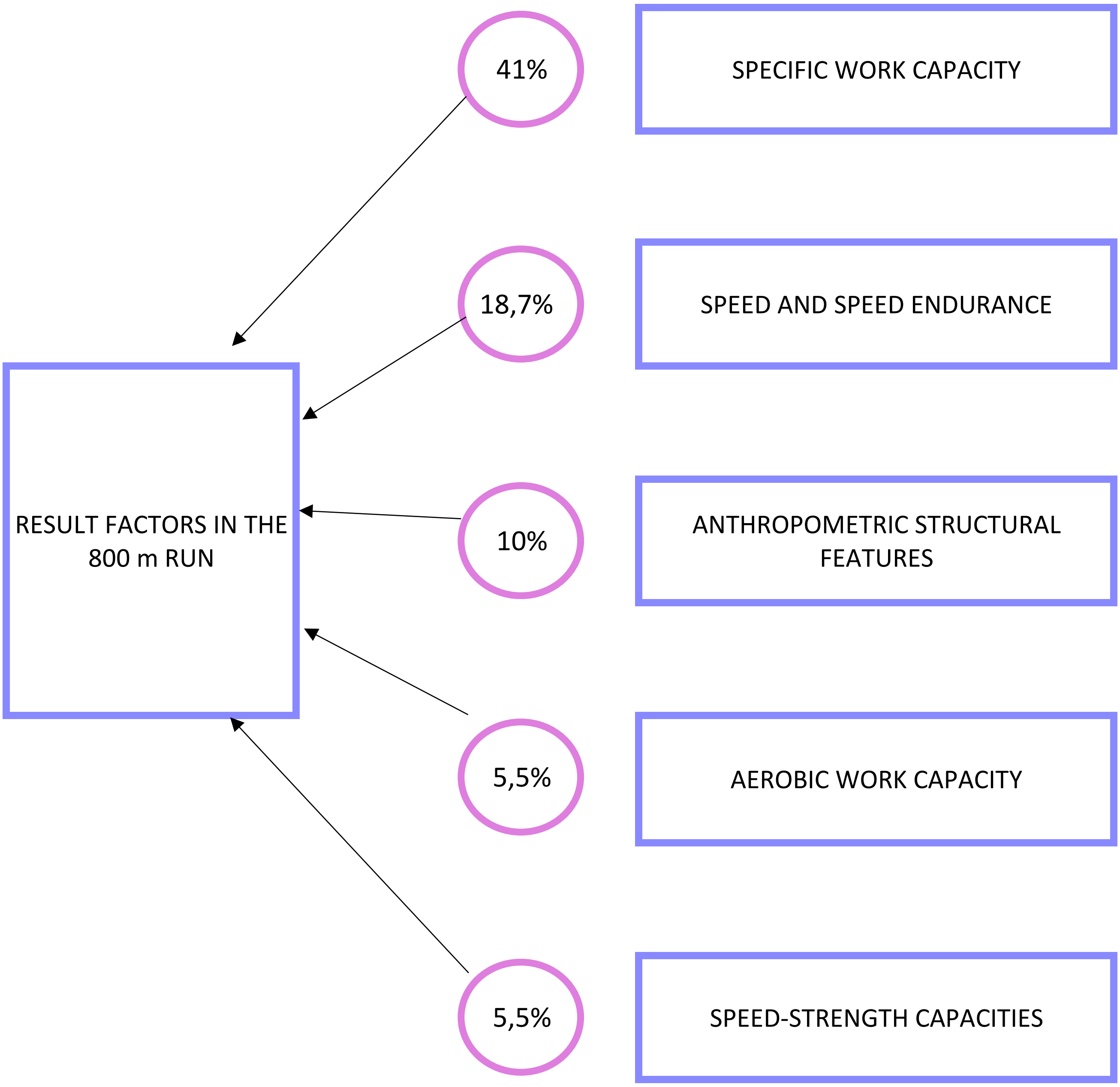


Fig. 6 Factor model of the 800 m run result

The result analysis shows that the sports score is predominantly determined by five factors, which together account for 80.7% of the original variance of the indicators.

The dependence of these factors and the readings of the correlation indicators support the optimization criteria in the development of the training processes, providing ample opportunities for modelling the adaptive improvement of the athlete.

III.3. MODEL FOR THE ORGANIZATION OF TRAINING LOADS IN SPECIAL PREPARATORY AND PRE-COMPETITION MESOCYCLE

Sports theory and practice recognise different combinations in the dynamics of volume and intensity in the different mesocycles of middle-distance running training, especially in terms of the volume and intensity increase features, which are defined as adaptation criteria by their current critical levels for each individual case.

Thus, the same absolute readings recorded in differently oriented mesocycles have different weights as adaptation estimates. The model allows for a shortened set of tests carrying information on anaerobic work capacity to assess the levels of adaptation of sports loads in the respective mesocycle. Tables 2 and 3

Table 2. Grades of adaptive levels - special preparatory mesocycle

Level	Score		Tests		
	Z	P	100	300	1000
EXCELLENT	2.0	97.73	11.76	38.00	2.36.30
	1.6	94.12	11.80	38.20	2.38.53
VERY GOOD	1.5	93.32	11.84	38.30	2.39.00
	0.7	75.81	11.90	38.60	2.43.10
GOOD	0.6	72.86	12.00	38.90	2.40.00
	-0.7	24.19	12.20	40.10	2.44.10
AVERAGE	-0.8	21.18	12.40	40.50	2.50.10
	-1.6	5.48	12.60	41.00	2.51.34
POOR	-1.7	4.45	12.70	41.50	2.55.35
	-2.0	2.27	12.90	42.00	2.56.00

In addition to estimates of adaptation levels, the model also offers regression approaches, through the same tests, which can identify weaknesses and strengths in the current state of training for making adequate management decisions in relation to the applied impacts.

Table 3. Grades of adaptation levels - pre-competition mesocycle

Level	Score		Tests		
	Z	P	100	300	1000
EXCELLENT	2.0	97.73	11.35	36.21	2.35.00
	1.6	94.12	11.40	36.80	2.35.40
VERY GOOD	1.5	93.32	11.42	37.15	2.35.80
	0.7	75.81	11.44	37.45	2.36.00
GOOD	0.6	72.86	11.62	38.00	2.38.10
	-0.7	24.19	11.80	38.30	2.41.02
EVERAGE	-0.8	21.18	11.90	39.00	2.43.00
	-1.6	5.48	12.20	39.20	2.44.20
POOR	-1.7	4.45	12.35	39.60	2.45.21
	-2.0	2.27	12.50	40.00	2.46.80

A significant contribution to the development of the model was the degree of dependence between the 800 m performance and the results from the tests conducted during the research period.

III. 4. PULSOMETRIC MODEL OF ADAPTIVE PROCESS

Changes in the heart rate under various physical loads are the basis of many tests for functional assessment of the cardiorespiratory system, and on this basis are generally acknowledged as an indirect criterion for the degree of physical exertion in natural environments, where now, with the help of modern microelectronics, their actual measurement poses no problem.

Given that the heart rate is a classic criterion for cardiovascular assessment in our study, it was essential to establish dependencies between the heart rate characteristics and adaptation processes during the applied running loads in the following directions:

- Heart rate behaviour in a state of "absolute" rest
- Heart rate behaviour in the process of specific motor activity (physical exertion)
- Heart rate behaviour during recovery phases (early and late)

In the course of our research, we found that the dynamics of the heart rate at rest is mostly affected and influenced by the magnitude and variability of the loads applied when running.

Fig. 7 shows a graph of the average heart rate of intermediate middle-distance runners measured at rest after waking up within a two-week training cycle and Fig. 8 shows the dynamics of the average daily running volume over the same period.

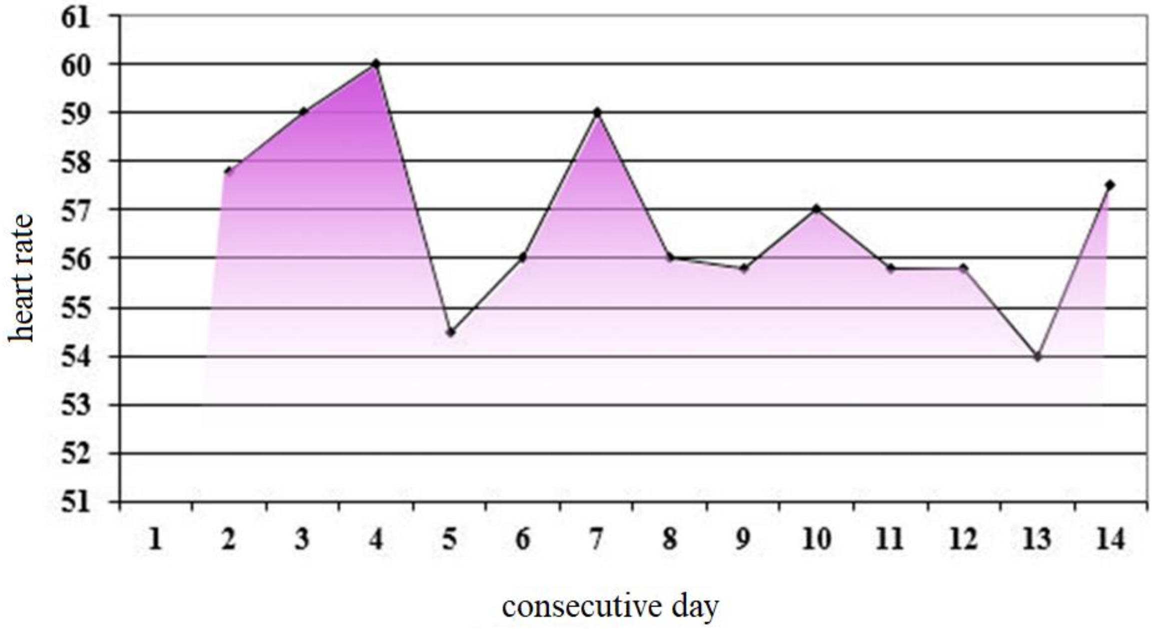


Figure 7. Average heart rate at rest in the morning

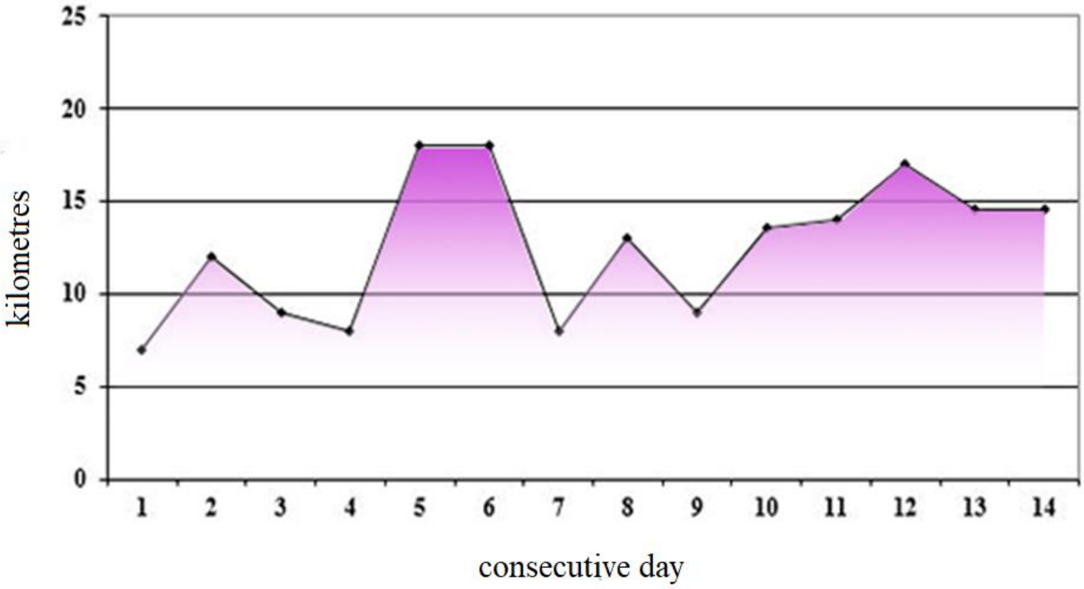


Figure 8. Dynamics of daily running volume

The comparative analysis between the two graphs quite clearly indicates that on the days following the increase in the volume of the training load, the heart rate also responded adequately to this increase. At the same time, by the end of the study period, when the total running volume increased cumulatively, a stabilization of the resting heart rate around the lower limits was quite evident, a circumstance which suggests an improvement in the preservation and an increase in the level of fitness. This hypothesis was confirmed by the results from the control tests conducted during the week following the end of the experiment. These results indicated a significant improvement compared to the baseline prior to the experiment in all indicators that correlated with the level of running endurance.

The model for the application of pulsometric criteria to the sports process in our study provided an opportunity to determine coaching decisions when reducing or maintaining daily planned running volumes, and the pulsometric data were definitely used as adaptation criteria.

III. 5. MODEL FOR IDENTIFYING THE CRITICAL SPEED AND CONVERTING IT INTO A ZONE ENDURANCE RANGE FOR 800 AND 1500 m RUNNERS

The model is a practically applicable method for the operational calculation of the critical speed and the efficiency range of the running effort, through test distances of 600 m, 800 m, 1000 m and 1500 m. For each of these lengths, a constant factor was calculated using a mathematical and statistical methodology, - for 600 m - 2.6, 800 m - 1.9, 1000 m - 1.4 and 1500 m - 0.9. The result obtained in the test in seconds was applied in the formula V=Y.K

where:

V – required critical speed
Y - individual test result
K - constant coefficient

Once the critical speed is reached, the efficiency range of the run, which is locked between the critical speed and the lower speed limit, is also calculated. / *The methodology is described in detail in the dissertation* /
For this range, depending on the individual impacts applied, we developed three work zones:

- **supporting** - applicable during the early preparatory or recovery period, which is characterized by a heart rate of 130 - 140 bpm, a speed during prolonged aerobic running of about 5 min./km with moderate blood and oxygen supply.

- **developing** - at a heart rate of 150 - 170 bpm, running speed of about 4.50 min./km, with high oxygen consumption, but still in aerobic mode.

- **optimal** - characterized by maximum oxygen consumption at a heart rate of 170 - 185 or more and a running speed of below 4 min./km.

The experiment we conducted for the performance in the indicated pulsometric zones during the research period allows us to put forward a practically applicable classification model for running performance for this category of athletes, Table. 4.

Table 4. Classification model of running performance within the range of the heart rate zones

Heart rate zones	up to 130 bpm	130-150 bpm	150-170 bpm	170-185 bpm	above 185 bpm
training effect	recovery	supporting	developing	optimal	specialised
impact	aerobic	aerobic	aerobic	aerobic-anaerobic	anaerobic
intensity zone	minimal	moderate	large	large	submaxima l
degree of load	low-medium	low-high	average-high	average-maximum	maximal
volume - km	at ease	5-12	8-10	5-8	individual

The model also derives criteria for evaluating the adaptive effect in running loads, by revealing the dynamics of the heart rate frequency in aerobic mode, evaluating the running sparingness and training effect based on the economy of the working heart rate and improving its recovery rate after exercising.

A model was also developed to control and evaluate the applied running loads in establishing the extent of the loads in the pulsometric zones.

The proper use of the results in terms of training effects and methods to determine the critical speed, control and evaluation of the degree of exertion in this category of athletes can be defined as an innovative approach that provides objective information for the adaptive course and optimization of the sports process.

III.6. MODEL FOR APPLICATION OF SPECIALIZED LOADS FOR BUILDING RUNNING STRENGTH

The issue of effective strength training of the athlete has long occupied a central place in sports practice theory but has not yet been adequately addressed in intermediate middle-distance runners, where more confidence is being placed on typical aerobic and anaerobic work.

The relevance of bringing this to the fore is that athletes need to maintain an optimal level of strength and coordination for long-term training over the running cycle - stride length and frequency.

The model we developed for typical strength endurance training is based on a training experiment with the subjects and two measurements over a six-week period in which the runners fulfilled the program shown in Table 5

Table 5. Work scheme for load training in the experiment

Day / Cycle	First three weeks	Second three weeks
Monday	Sleigh pulling 10x100 m	Multiple stride jumps 10x100 m
Tuesday	Aerobic running 4-6 km	Aerobic running 4-6 km
Wednesday	Incline running 10x100 m	Incline running 10x100 m
Thursday	Aerobic running 4-6 km	Aerobic running 4-6 km
Friday	Sleigh pulling 10x100 m	Multiple stride jumps 10x100 м
Saturday	Recovery run 395 km	Recovery run 3-5 km

The trials were video recorded and computer analysed, resulting in the following indicators:

- - results in the 800 m run (seconds)
- - average running stride length for each person (centimetres)
- - average running stride frequency for each person tested (number per sec)
- - time taken to run the last 200 m of the 800 m distance (seconds)

- average running stride length in the last 200 m for each person tested (centimetres)

- - running stride frequency in the last 200 m for each person tested (number per sec)

- heart rate immediately after completion of the run for each person tested (bpm).

The results of the first and second trials are presented in variational form in Tables 6 and 7

Table 6. Variation indicators of the readings from the first trial

Indicator	min	max	$\bar{x}$	R	S	V
800 m (sec)	125.73	146.97	136.39	21.24	6.41	41.16
Stride length - cm	167	196	186.36	29	7.86	61.83
Stride frequency – no./sec	2.86	3.39	3.15	0.83	0.13	0.02
Time of last 200 m sec	32.70	37.00	34.81	4.30	0.91	0.83
Stride length 600-800 m cm	165	196	182.96	31	8.55	73.16
Stride frequency 600-800 m no./sec	2.86	3.39	3.14	0.53	0.14	0.01

Table 6. Variation indicators of the readings from the second trial

Indicator	min	max	$\bar{x}$	R	S	V
800 m (sec)	123.00	140.97	131.98	17.97	6.58	43.00
Stride length - cm	165	203	188.48	38	7.93	47.00
Stride frequency – no./sec	2.85	3.63	3.18	0.78	0.15	0.02
Time of last 200 m sec	32.27	36.20	34.22	3.93	0.91	0.83
Stride length 600-800 m cm	171	200	186.82	29	8.28	58.48
Stride frequency 600-800 m no./sec	2.82	3.45	3.13	0.65	0.15	0.02

The data from the pulsometric trials were used to establish whether the subjects actually achieved their momentary maximum capacities in the 800 m run. Each athlete finished the run with a heart rate close to the maximum -/185-200 bpm/, allowing us to claim that the running task had been completed.

The result analysis indicates that the average readings in the second trial were significantly improved over the time of the experiment where preference was given to the specific strength endurance and that each of the applied training tools for improving the running strength had an effect on:

- • the end result in the 800 m run
- • the increase in the average running stride length, which positively affected the 800 m run result
- • the improved running time of the last 200 m of the 800 m distance

• the increased average stride length in the last 200 m

The applicable and innovative worth of the model is that it proposes a tested work scheme for specialized loads, classified by the specific relevance for such category of athletes and in that it requires special running strength to be built up systematically during the annual cycle, and not as before only during the preparatory period using traditional means of strength building.

III.7. EXPERIMENTAL MODEL OF ADAPTIVE DEVELOPMENT IN THE MACROSTRUCTURE OF TRAINING INTERMEDIATE 800 m RUNNERS

The organizational structure of long-term adaptive changes associated with specific changes in sports performance is constructed from gradual steps expressed by an algorithm of time-dependent and cumulative adaptive changes. In this regard, optimization of this algorithm requires precision in the sequence of application of training stimuli and temporal pauses required to cumulate adequate adaptive changes.
The model we prepared for the adaptive development in the macrostructure of training is based on the following adaptive criteria that emerged in the course of the study:

1. Approximate result of 800 m base run from 2,00 to 2,10 min.

2. Baseline of the main indicators of the adaptive levels of the specific physical work capacity:

- • Running speed indicating the intensification of the glycolytic mechanism in the energy supply of the run 4.08-4.10 min. per km. Approximately up to 4 m/sec.

  • Recommended maximal oxygen consumption millimetres per minute per kilogram of body weight 57.30-57.50 ml.

- • Speed possibilities - alactate capacity efficiency - 100 m standing start result of 11,50-11,60 sec.

• Glycolytic work capacity - speed endurance – 300 m standing start result from 37.50 to 38.50 sec.

- • Speed and strength capabilities - result of tenfold straight jump of 28.50-29.30 meters.

• Aerobic work capacity for a steady 8 km run in 29.80-30 min. with lactate accumulation at the end of the run of about 4.5-5.00 mill moles.

These criteria, based on our research, characterize the average statistical morphofunctional model of the intermediate 800 m runner.
Assigned theoretical loads by volume, intensity and running strength were prepared in advance for a period of 15 weeks in which to track mesocyclic changes in the levels of these indicators.

The analysis of the dynamics of volume and intensity in the experimental model for adaptive development provides grounds to draw the following more important conclusions related to the processes of modelling long-term adaptation in the macrocycle when training intermediate runners for the 800 m run:

• The expected positive changes in the adaptive levels of the main indicators that characterize the development of sports performance will depend on: baseline characteristics, the speed and speed and strength indicators, as well as on the rates of development of the functional and biological characteristics.

- The ratio of the volume and intensity of the applied running loads is essential, which must be determined by the bioenergetic characteristics of the running effort. With typical aerobic and alactate loads, at certain times the simultaneous increase in volume and intensity is justified and effective.

- It is preferable with anaerobic loads in mixed and anaerobic modes to follow the rule of the inverse relationship between volume and intensity, i.e. the change in one parameter is accompanied by the opposite sign change in the other.

The effectiveness of the adaptive process in our proposed model is largely determined by the smooth transition of running loads from aerobic-anaerobic mode to anaerobic-aerobic and glycolytic gradually from the preparatory mesocycles to the special preparatory and competitive ones.

We believe that mesocycle planning and tracking changes in the adaptive levels of the main indicators of specific work capacity with these runners will be an innovative approach for evaluating the effectiveness of the adaptive process and its management.

III.8. CLASSIFICATION MODELS OF TRAINING LOADS FOR MIDDLE-DISTANCE RUNNING

The generalised analysis of the results in the seven models of adaptive development presented so far, as well as the running loads applied in the research by volume and intensity, allowed for the development of practically applicable integral sports and pedagogical models for specialized running tools in the training of intermediate runners. The principal basis for formation of the models is based on the energy supply regimen, the sports-pedagogical content, the bias of training and parameters of the running loads. This formulation opens up broad opportunities for optimizing the adaptive process by objectifying the term training effect. This facilitates the planning and control of the optimal load algorithm in the micro and mesostructure of the training process on the basis of the so-called positive transfer of the training effect, **i.e. purposefully modelling of an adaptive effect.**

Quantitative work schemes were drawn up to assist in the application of the running performance models in different aerobic modes and mesocycles, for the 800 and 1500 m runs under the speed loads in Tables 8 and 9.

Table 8. Illustrative work scheme of the volume of speed training for 800 m. in a single training session

Mesocycles / Running distances	Special Preparatory			Pre-competition		
	February	March	April	May	June	July
50-60	–	8-10	8-10	8-10	10-12	8-10
100	–	8-10	8-10	8-10	10	8-10
150	–	6-8	8-10	6-8	6	4-5
200	6-8	8-10	6-8	4-6	5	4-5
300	4-6	6-8	4-6	4-6	4	3-4
400	2-4	3-4	2-4	3-4	2-3	2-3
600	2-3	3-4	2-3	2-3	2	2

Table 9. Illustrative work scheme of the volume of speed training for 1500 m. in a single training session in Ch. b

Mesocycles / Running distances	Special Preparatory			Pre-competition		
	February	March	April	May	June	July
50-60	–	10-12	10-12	10-12	10-12	10
200	–	10	10-12	12	10	8
300	–	10	8	6	4-5	3-4
400	4-5	6-8	6	4	3-4	2-3
600	3-4	4-6	4	4	3-4	3
800	2-3	4	4	3	2-3	2

We also developed a method for establishing the running pace in high-speed activities for running distances from 100 to 1500 m in maximal high and optimal intensity, as well as an 800 m running schedule successfully tested in the research period in search of an adaptive effect.

IV. ADAPTIVE CHANGES IN AEROBIC WORK CAPACITY RESULTING FROM THE APPLICATION OF RUNNING LOADS WITH SOCCER PLAYERS

In interval variable sports, most relevant are the processes for building the aerobic capacity and its effective use for increasing specific sports performance. In this regard, the maximal oxygen consumption / VO_2 max/ and its diagnostic readings are accepted as the main criteria for the level of aerobic capacity. In this line of thought, in order to enhance the level of sports training with soccer players, we developed and tested two models.

IV.1. MODEL OF SPECIFIC WORK CAPACITY WITH SOCCER PLAYERS

Research was focused on the following main tasks:

- • Study the dynamics of changes in aerobic capacity (VO_2 max – mL. min. kg)
- • Study the dynamics of changes in the running capacity (results from the Cooper test)

• Derive a model for planning the running loads in the microcycles of various natures and biases in soccer training.

The duration of the research cycle was 12 working weeks in the so-called preparatory running period.

The studies included spiroergometric sampling, a 3200 m run (a modification of the Cooper test) and a PWC_{170} test.
The running performance was reported by sum total on a weekly basis, as well as the duration and nature of the rests in the running regimen shown in Table 10.

Table 10. Weekly dynamics of the volume of running loads

Седмици № / No. week / Training means	1	2	3	4	5	6	7	8	9	10	11	12
Working days (no.)	6	7	6	5	5	5	5	5	6	5	5	5
Exercise sessions (no.)	8	10	9	7	8	7	7	7	9	7	7	7
Days off (no.)	1	–	–	1	1	1	1	1	1	1	1	1
Steady running (km)	21	30	20	18	15	16	19	15	20	14	15	15
Variable running (km)	–	6	4	2	4	2,3	1,9	2,8	–	2	–	–
Interval distance runs 50-200 m (km)	–	–	2	1,6	2	2,6	2,8	2,4	2,8	2	2,9	2
Interval distance runs 200-600 m (km)	–	3	4	2	–	–	–	–	2	1,6	3,4	2
Interval distance run over 600 m (km)	3	1,8	1,8	2	–	–	–	–	1,8	–	–	–

Two tests were conducted, one in the first week at the start of the preparation and the second in the last week of the intensive running period, the results of which are shown in Table. 11

Table 11. Dynamics of the variation analysis results from the two studies

	Oxygen consumption mL/kg				3200 running speed m m/sec			
	X average	X maximal	X minimal	Standard deviation	X average	X maximal	X minimal	Standard deviation
1st week	53,98	60,16	50,20	2,82	4,35	4,52	3,95	0,16
12th week	55,52	62,20	49,70	3,24	4,47	4,57	3,97	0,15

The analysis of the variation table shows that the running training load exerted during the 12-week stage had a positive effect, where the mean VO_2 max level increased from 53.98 to 55.52.

This was also confirmed by the PWC_{170} sample, as indicated in Figs.9 and 10

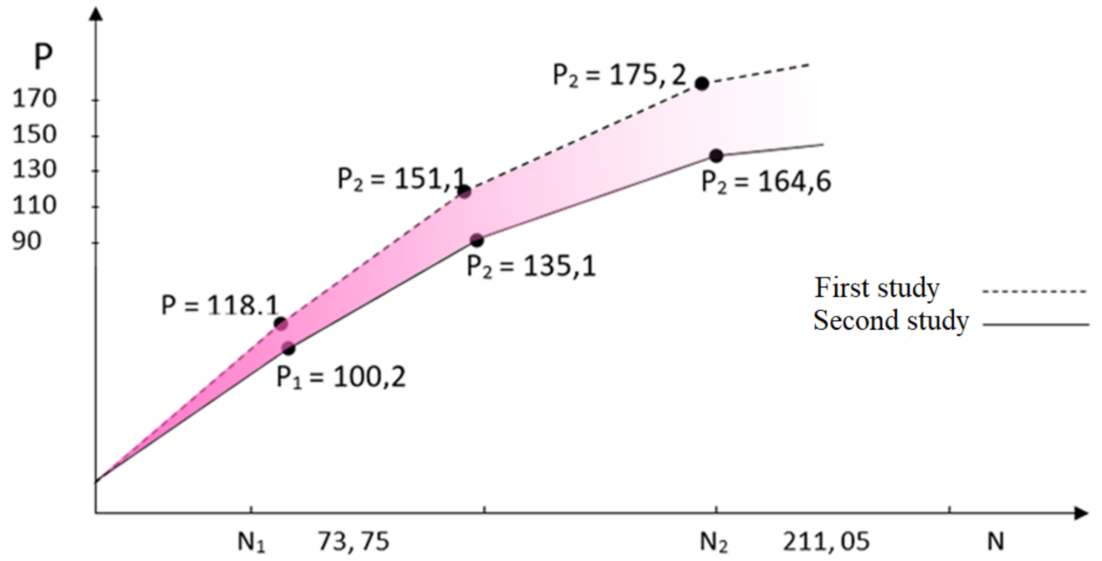


Figure 9. Heart rate dynamics according to the applied continuously increasing load

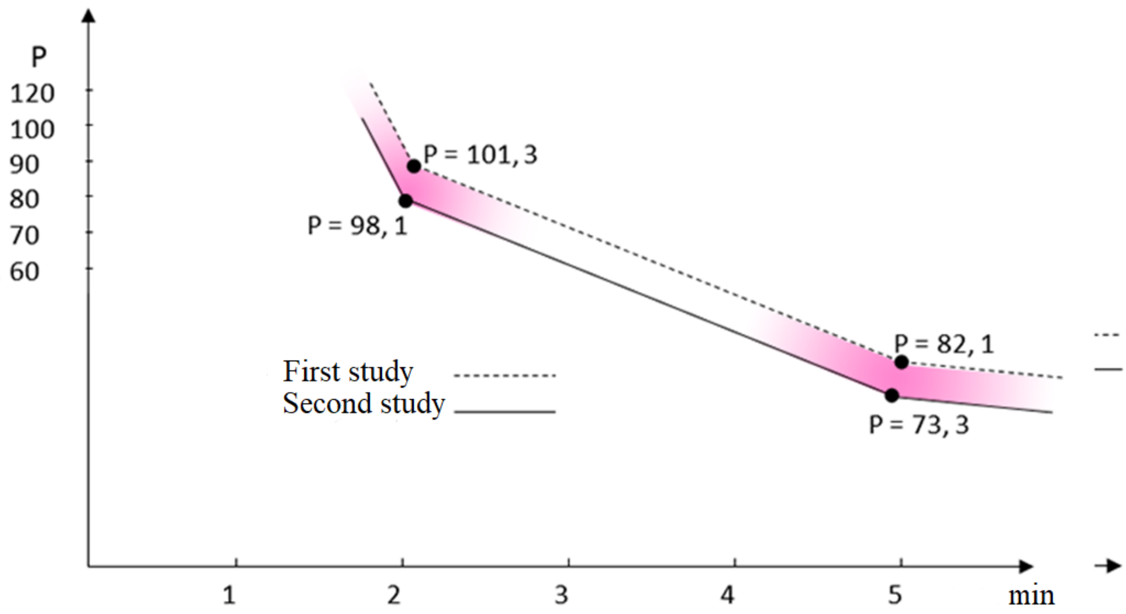


Figure 10. Heart rate dynamics from the second to the fifth minute of recovery after PWC$_{170}$ test

Fig.9 unambiguously shows that in the first study at the start of their training, soccer players were still not prepared for the aerobic momentary capacity and the heart rate rose rapidly, which shortened the sampling time, recording low work capacity. This can also be seen in the recovery of the heart rate following the activity from the first to the fifth minute in Fig.10.

Of interest is the comparison with the results in the 3200 m run, a modification of the Cooper test. The dynamics of the changes are identical to those of VO_2 max PWC_{170}. Over the entire study period, the average speed of the - 3200 m run rose from 4.35 m/s to 4.47 m/s (from 12.15 to 11.55 min).

The analysis of the dynamics of the indicators under study shows that the applied training methodology has increased the general adaptive abilities of the athletes. The achieved level of general adaptive capacities was preserved for 12 weeks. This confirms the positive training effect of the applied methodological approach in building the training process.

IV.2. CLASSIFICATION MODEL OF RUNNING LOADS, INTENSITY AND EVALUATION OF CRITICAL ADAPTIVE LEVELS

The model was developed on the basis of five pre-modelled test training sessions / detailed in the dissertation / which provoked different adaptive effects. The results of these activities, which were tested purposefully and selectively in the context of the entire research period, allowed to distinguish a classification model of the running loads, hopefully, useful for sports practices, Table 12.

Table 12. Classification model of running loads for training soccer players

Running load bias	**Building general endurance**						**Building speed endurance**					
Nature of the load	Aerobic		Aerobic Anaerobic		Anaerobic Aerobic		Anaerobic Glycolytic			Anaerobic, alactate and glycolytic		
Working heart rate	140-160 bpm		160-180 bpm		170-190 bpm		from 170 to maximum			from 170 to maximum		
Length of running distance	3-10 km	3-8 km	3-8 km fartlek	1000 m	600 m	400 m	200 m	150 m	100 m	50-80 m	20-40 m	start to 20 m
Intensity (running speed)	4,30-6,00 min/km		3,20-4,30 min/km		75-85% of capacity		85-95% of capacity			90-100% of capacity		
Number of repetitions	1-3		1-6		3-10		5-12			8-16		
Duration of rest	3-10 min		1-5 min		1-3 min		3-5 min			20 sec – 3 min – 8 min		
Nature of rest	Combination of passive and active rests according to specific conditions and other load parameters											
Total volume in one session	3-10 km		3-8 km		2-4 km		1-2 km			0,3-1,2 km		

We composed the model on the quantitative and qualitative regularization of the results obtained in the following adaptive parameters:

- Sports and pedagogical bias of running loads
- Biochemical nature of running loads
- Optimal readings of working heart rate
- Length of distances run
- Running speed under certain different conditions
- Number of running repetitions
- Duration of rests between different runs and sets
- Nature of rests
- Optimal volume limits in one session

The essence of the model classifies running loads into the three main aerobic zones on the basis of which detailed aerobic, aerobic-anaerobic, anaerobic-aerobic and anaerobic workout running models have been elaborated.

The use of the basic model facilitates the system for operational planning of training according to the specific adaptation tasks in the meso- and macro-structure of training.

The model avails of a method for specifying the work intensity for speed endurance and a model for controlling and assessing complex game endurance, for which a study was conducted using expert-selected tests, Table 13.

Table 13. Variational analysis of the results of the study of soccer players

	Test No.	X max	X min	$\overline{X}$	S	V%	R
Speed power	Standing long jump (cm)	286	238	257,32	12,90	5,01	48
	Standing triple jump (cm)	830	690	758,77	36,77	4,84	140
Start and takeoff acceleration	30 m standing start run (sec)	4,75	4,40	4,53	0,15	2,09	0,35
Speed endurance	10x20 m in 20 sec - average time (sec)	3,32	2,88	3,11	0,16	2,42	0,44
Biological parameters	Afterload heart rate (bpm)	190	150	169,57	8,35	4,93	40
	Afterload lactate - mmol	8,9	5,7	7,56	0,91	12,01	3,2
Overall endurance	2000 m run (m/s)	4,34	3,33	3,82	0,26	6,96	1,01

The variance analysis and further supplemented statistical processing of the results provided an opportunity to elaborate on estimates of the critical levels of the specific physical work capacity, Table 14.

Table 14. Assessment of critical adaptive levels of fitness training

Assessment test	Excellent	Very good	Good	Average	Poor
2000 m (min)	7,14	7,40	8,16	8,43	9,22
10x20 m (sec)	2,63	2,79	2,95	3,13	3,29
30 м standing start	4,05	4,20	4,39	4,54	4,68
Standing long jump (cm)	294	282	268	257	260
Standing triple jump (cm)	8,75	7,40	7,96	7,60	7,43

The effectiveness of the applied approaches in sports can be evaluated by the absolute readings of the results on the five-point scale in Table 14.

Based on the analysis of the results of the overall study of the model and the possibilities to assess the running and overall fitness training, we recommend that building specific endurance be carried out according to the following scheme:

- • Overall aerobic endurance
- • Strength endurance and dynamic strength in the aerobic-anaerobic transition zone.
- • Speed and speed-strength endurance in terms of the glycolytic and creatine phosphate mechanism - lactate and alactate endurance.

• In conclusion, on the basis of the adaptive changes in the training of soccer players during the study period and the results of the conducted studies, we identified an average statistical morphofunctional model of the contemporary soccer player, who should be distinguished by playing efficiency and higher workability, a high level of motor qualities and coefficient of efficiency for an extended playing time.

V. CONCLUSIONS, RECOMMENDATIONS AND SCIENTIFIC CONTRIBUTIONS OF THE THESIS

5.1. Conclusions

The analyses of the conducted research and experiments on the development of adaptation models for building specialized endurance in the training of athletes

by means of running loads provoked conclusions that provide new opportunities for increasing the effectiveness of the training and sports process.
Given the hypothesis, the goals and objectives achieved in the research can be rudeced to:

1. The specific running endurance established in theory and practice, and hence the specific work capacity, is an objective criterion for determining the relevant adaptive potential and emerging functional changes, where every running exercise and load is performed in a zone encompassed by bioenergetic and motor parameters. The individual readings of these indicators represent the critical values of the specialized specific running capacity.

2. Increasing the adaptive capacities and enhancing athletic performance with running loads are now definitely also related to refining the specific strength capacities of athletes. In support of this claim of ours are the findings in the applied experiment, where basic strength endurance exercises have positively affected the sports result in the 800 m and the running stride parameters, especially in the last 200 m.

3. The study of the correlative-factor structure of the running indices reveals broader possibilities for modelling the adaptation processes in athletic training by means of control and evaluation of the term and cumulative effects. This allowed for the introduction of predictive models of performance in the 800 m run.

4. The dynamic balance of the volume of sports loads obviously has a positive effect on running performance with this category of athletes, but only up to the point where it gets close to the maximal level.
The innovative approach we reveal for further growth in the sports result is no longer in the maximum volume, but in optimizing its internal structure, and more specifically in optimizing the ratio between the different means and methods through specific models.

5. Achieving good results in specialised endurance training definitely depends on the individual potential of the athlete, and to what extent he is an anaerobic or aerobic subject.
With the anaerobic type, the anaerobic share in the energy supply increases significantly faster at a relatively lower running speed.
What we ascertained in the category of studied athletes was that the aerobic type has a higher resistance to aerobic provision at relatively high power of running effort.
At certain stages of the sports process with recovery and preservation effects, the loads between the aerobic and anaerobic threshold are highly effective in enhancing adaptive development.

6. Studies of the dependence of the heart rate with running loads have found significant changes in adaptation in terms of dynamics and rest, workout and recovery phases.
In all three cases, these are influenced by the variability of the running loads and reflect the nature of the adaptive changes and can successfully serve to assess the applied running loads.
These findings suggest that the developed pulsomtric models are an objective basis for optimizing the development of short-term adaptation and selection of the loads.

7. The classification models of the different types of running impacts definitely allow for the optimization of the adaptive process by objectifying the loading effect.
This expands the possibilities of planning the sport process entirely on the basis of the so-called positive transfer.

8. When modelling the preparation for specialized endurance, three relevant features of the running loads can be highlighted:

• speed and speed-power indicators are harder to improve, while functional indicators are significantly faster to enhance.

• the volume-to-intensity ratio is largely determined by the bioenergetic characteristics of the running loads and, in this respect, in an aerobic running mode of work, which is more applicable to intermediate athletes, their simultaneous increase is used with greater success. With mixed and anaerobic mode loads, we found that altering any one of these parameters at the expense of the other produces positive results.

- The efficiency of the adaptive processes is more significant when transfusing running loads from aerobic-anaerobic to anaerobic-aerobic mode.

9. The adaptive capacities of a training soccer player are defined by the level of VO_2 max and the endurance running effort and are developed in three main fields - continuous steady running, continuous alternative, and interval running.

The classification structures in these fields are based on up-to-date new categories of indicators:

• step-by-step selection of highly effective training tools
• biological features of the athlete
• targeted specific impacts according to the nature of the soccer game
• highly effective sports-pedagogical content with precisely oriented parameters of the load

10. The derived models of the structure and the content of training for specialized endurance through running loads prove to be an objective basis for building the sports process by optimizing:

- • standardizing load impacts by volume and intensity

• assessment of current individual adaptation levels and tailoring sports programs according to the adaptive capacities and current potential of the athlete

5.2. Recommendations

Based on the results of the research and above all on the conclusions drawn, we have summarized the main recommendations in relation to the construction of models for adaptive development in the training process for specialized endurance through running loads:

• 1. The individual running adaptation potential of the athlete should be determined on the basis of speed and running duration dependence for each separate stage of training.

• 2. Sports training with running loads aimed at expanding the adaptive capacities of the athletes to specialized endurance should be carried out in accordance with the specified adaptation zones in the individual stages and modes of work.

• 3. The models developed to determine the required and critical speed in athletic training and performance and in the pulsometric zones of the loads should be used as an objective basis for predicting and evaluating the effects of ongoing adaptation impacts.

- 4. The research found that the purposeful building of specific adaptive abilities for specialized endurance through running loads requires the utilisation of specific strength abilities.

• From this point of view, we propose an innovative approach that specialized strength running loads find their decisive place in strength endurance training for this category of athletes as well.

- 5. When optimizing running loads for adaptive capacity development, sports educators should consider the quantitative characteristics based on the correlation-factor structure of the running potential.

- Of significance is the predictive regression structure of the running ability and the correlation structure of the training potential of the loads.

• 6. The effectiveness of sports loads should be programmed based on the revealed dependencies and the derived correlation and regression models on grounds of the critical levels of bioenergetic and pulsometric work capacity.

• 7. In programming running loads for training intermediate athletes, we recommend the use of the models we developed in the various modes of work and the individual programming tasks.

• 8. When using the running methods in endurance training of soccer players, the following methodological requirements should be observed: during the overall training, continuous steady running should be applied for the vigorous stimulation of aerobic performance, with more noticeable attention paid in the first four weeks of training.

• variable continuous running of appropriate volume and intensity should be applied throughout the entire training period.

• interval running in its greatest variety should be the fundamental method for building the soccer player's general adaptive capabilities. It is of decisive significance and should be applied from the beginning of the major training cycle and continued uninterruptedly.

• The peculiarities of interval loads require them to be planned and dosed on the basis of balance - running speed, distance and volume of running exercises, duration and nature of rest intervals.

In conclusion, we recommend that the running load classification models we developed to be used in the sports process of soccer players for targeted programming of training.

5.3. Contributions

The contributions of the thesis boil down to five major results, which represent an innovative approach to solving problems related to the interpretation of the adaptive development in training the athlete for specialized endurance in middle-distance runs, as well as in soccer, where the quality of endurance is of fundamental importance.

1. Models were developed, based on the relationship between speed and duration of running effort, to predict the current running potential.

2. Based on the correlation-factor structure of the specific work capacity, estimates of the current adaptation potential with runners and soccer players were developed.

3. Models have been developed to predict and evaluate the potential of the running loads in the various oxygen regimens and the program tasks related to them.

4. Classification models of running loads for middle-distance running and soccer have been developed, as well as morphofunctional models of the intermediate runner and modern soccer player - distinguishing efficiency, capacity and high level of physical properties.

5. The developed theoretical framework for modelling the adaptive processes in preparing athletes for specialized endurance training, through running loads, has universal applicability, positively contributing to the effectiveness of the training and sports methodologies.

Publications related to the dissertation

1. A Current Approach to Developing Endurance for Intermediate Skilled Middle-distance Runners, Journal of Sport Science issue 3,4/2021 ISSN 1310-3393
2. Evaluation of the Adaptive Effect in the Training of Runners at Medium Distances, Journal of Sport Science issue 3,4/2021 ISSN 1310-3393
3. Pulsometric Criteria for the Classifications of Training Overload, Vocational Education, 2021, No. 6, pp. 545-549. ISSN 1314-555X; COBISS.BG-ID 1240229092
4. Control of Training, a Fundamental Factor for Achieving High Results. Modern Trends of Physical Education and Sport 2021 ISSN 1314-2275
5. Features of the Load in Training Middle-distance Runners, Modern Trends of Physical Education and Sports 2022 ISSN 1314-2275