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# Increasing the level of preparedness of 400 m hurdles runners by means of hypoxic exposure as the basis for achieving a sporting result

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***Purpose:*** *establish the dependence of the result of 400 m hurdles on the morphofunctional, physical and hypoxic preparedness of athletes.*

***Material & Methods:*** *the study involved 18 athletes aged 16–18 years who had the level of preparedness of the first sports category and the candidate master of sports in the 400 m hurdles. To establish the role of hypoxic training in increasing anaerobic performance, multiple regression analysis was used, which determines the role of each factor in the adaptation mechanism, as well as in the performance of test tasks.*

***Results:*** *determined the importance of training physical qualities, morphofunctional abilities, hypoxic stability for the successful manifestation of technical skill in competitive conditions.*

***Conclusions:*** *the inclusion in the training process of interval hypoxic training contributed to a more significant increase in the anaerobic performance of 400 m hurdles runners.*

**Keyword:** *adaptation; hypoxic performance; 400 m hurdles; anaerobic power.*

## Introduction

The level of sports preparedness is increased due to the development of functional capabilities, which is carried out through physical, technical-tactical, psychological and hypoxic training activities. The conditional division of the preparation process into relatively independent directions makes it possible to streamline the consciousness of its structural state, as well as systematize the methods and means, and thus develop a system for monitoring and controlling the training process [1–3, 8; 9; 11; 23; 24].

In real conditions of the training process, none of these aspects of training does not manifest itself in isolation, but is in a constant relationship [4; 12; 13; 18; 19].

It is proved that the achievement of sports results is possible only with a harmonious combination of all aspects of preparedness [10; 14; 15].

This scientific principle is particularly important in the preparation of 400 m hurdles runners. Running the 400 meters, and especially with the barriers, is one of the most difficult sports, which the researchers call "running killer" [21].

Some studies show that the most important factors that determine the severity of physical activity during a 400 m run with barriers is the level and duration of exposure to hypoxia [20; 22; 25], as well as sensitivity to it [5–7; 16; 17]. The lack of objective research materials on the technology of hypoxic training of 400 m hurdles runners and determined the direction of our research.

**Purpose of the study:** establish the dependence of the result of 400 m hurdles on the morphofunctional, physical and hypoxic preparedness of athletes.

## Material and Methods of the research

The study involved 18 athletes aged 16–18 years old who had the level of preparedness of the first sports category and candidates for the master of sports in the 400 m hurdles.

The basis for building training sessions and sessions of anaerobic effects was a 10-day microcycle. After each training session, the load of the hypoxic exposure was applied alternately: 10 sessions of interval hypoxic influence during the return breathing into the closed space.

To solve the set tasks, the following research methods were used: analysis of scientific and methodological literature; pedagogical observation; pedagogical experiment; telepodometry; methods for determining the functional state of barrierists; method of interval hypoxic training; methods of mathematical statistics.

To establish the role of hypoxic training in increasing anaerobic performance, multiple regression analysis was used, which determines the role of each factor in the adaptation mechanism, as well as in the performance of test tasks.

## Results of the research

For successful management of the training process, it is necessary to determine the importance of training physical qualities, morphofunctional abilities, hypoxic stability – for the successful manifestation of technical skills in competitive conditions.

The equations of mathematical models depend on a sporting result, on morphofunctional parameters, physical and technical readiness, hypoxic stability at the beginning and at the end of the preliminary basic training phase. The calculated ratio explains 99.9% of the variation of the parameters studied. Such a mathematical model is defined by the following equation (formula 1):

$$W_{400\,w/h}=7{,}64xSBV+6{,}72xMBV+5{,}41xF_{expiration}+3{,}06x\,VI-4{,}06xIHST-2{,}75XI_{Ru}-2{,}06xh_f-1{,}75xL_f+1{,}63Xi_{Ro}-1{,}36xF_{inhalation}-1{,}26xHR-1{,}02xL_b+0{,}97xBP_{syst.}+0{,}87xBP_{diast}-0{,}53xL_f-0{,}36xVC-0{,}09xW_b, \quad (1)$$

*where $W_{400\,w/h}$ – 400m hurdling result; SBV – systolic blood volume; MBV – minute blood volume; $F_{expiration}$ – forced expiration; VI – vital index; IHST– index of Harvard step test; $I_{Ru}$ – Ruffier index; $h_f$ – height of the arch of the foot; $I_{Ro}$ – Robinson index; $F_{inhalation}$ – forced inhalation; HR – heart rate; $L_b$ – body length; $BP_{syst}$ – systolic blood pressure; $BP_{diast}$ – diastolic blood pressure; $L_f$ – foot length; VC – vital capacity; $W_b$ – body weight.*

Thus, the analysis of the presented model of the sports outcome dependence on morphofunctional indices shows that the most important determinants are systolic blood volume – 18,2%, minute volume of blood and forced exhalation – 12,8%.

Applying the method of reverse stepwise regression, the function of multiple regression can be simplified, where only the most important factors that explain 99.2% variation of the investigated factors remain in the final model (formula 2):

$$W_{400\,w/h}=4{,}64xSBV+4{,}58xMBV+3{,}72xIHST+2{,}65xh_f+2{,}36xF_{expiration}, \quad (2)$$

*where $W_{400\,w/h}$ – 400m hurdling result; SBV – systolic blood volume; MBV – minute blood volume; IHST – index of Harvard step test; $h_f$ – height of the arch of the foot; $F_{expiration}$ – forced expiration.*

At the end of the preliminary preparation stage, the influence of each factor of the morphofunctional system changes somewhat (formula 3):

$$W_{400\,w/h}=7{,}64xSBV+8{,}02xMBV+4{,}51xF_{expiration}+2{,}36xVI-2{,}76xIHST-1{,}75xIR_u-1{,}62xh_f+1{,}23xIR_o-1{,}06xF_{inhalation}-3{,}26xHR-1{,}55xR_b+0{,}95xBP_{syst.}+0{,}83xBP_{diast.}-0{,}72xL_h-1{,}27xVC-0{,}07xW_b, \quad (3)$$

*where $W_{400\,w/h}$ – 400m hurdling result; SBV – systolic blood volume; MBV – minute blood volume; $F_{expiration}$ – forced expiration; VI – vital index; IHST– index of Harvard step test; $IR_u$ – Ruffier index; $h_f$ – height of the arch of the foot; $IR_o$ – Robinson index; $F_{inhalation}$ – forced inhalation; HR – heart rate; $L_b$ – body length; $BP_{syst}$ – systolic blood pressure; $BP_{diast}$ – diastolic blood pressure; $L_f$ – foot length; VC – vital capacity; $W_b$ – body weight.*

The analysis of the final model actually confirms the level of significance of the factors established at the beginning of the experiment: SBV – 11M5%, MBV – 19,6%, and VI – 11,1%. The equation of the inverse step-by-step regression leaving only 4 factors, the value of which significantly influences the result of 400 m hurdles (formula 4):

$$W_{400\,w/h}=4{,}87xSBV+7{,}96xMBV+4{,}31xF_{expiration}+3{,}15xHR, \quad (4)$$

*where $W_{400\,w/h}$ – 400m hurdling result; SBV – systolic blood volume; MBV – minute blood volume; $F_{expiration}$ – forced expiration; HR – heart rate.*

Indicators of physical preparedness of an athlete contribute to the manifestation of his technical abilities directly during the overcoming of the barrier distance. Each physical quality has its own peculiarity in achieving a sporting result. So, there are defining qualities, and there are satellite or complementary. At the beginning of the preliminary basic preparation stage of the equation of a mathematical model of the dependence of a sporting result on the level of development of physical qualities is as follows (formula 5):

$$W_{400\,w/h}=3{,}52xR_{400}+4{,}06xR_{100b}+0{,}11xR_{100}-1{,}09xR_{20b}+0{,}17xR_{60}+0{,}81xR_{30}+0{,}08xJ_u-0{,}1xJ_5-0{,}09xJ_s, \quad (5)$$

*where $W_{400\,w/h}$ – 400m hurdling result; $R_{400}$ – result of a flat race on 400 m from a crouch start; $R_{100b}$ – result of 100 m bounded run; $R_{100}$ – result of 100 m running from a crouch start; $R_{20b}$ – bounded run 20 m on one leg; $R_{60}$ – result of 60 m running from a crouch start; $R_{30}$ – result of 30 m running from a crouch start; $J_u$ – result of jumping up according to Abalakov; $J_5$ – result of a five-fold jump from the spot; $J_s$ – standing long jump.*

The conducted analysis of multiple regression, which shows the role of each indicator in the result of a 400 m hurdles, established influential factors for the result in a 400 m hurdles: a 100 m bounded run; 400 m running from a crouch start and bounded run 20 m on one leg.

The equation of stepwise inverse regression leaves only two significant factors for the result in the 400 m hurdles (formula 6):

$$W_{400\,w/h}=3{,}059xR_{400}+4{,}387xR_{100b}, \quad (6)$$

*where $W_{400\,w/h}$ – 400 m hurdling result; $R_{400}$ – result of a flat race on 400 m from a crouch start; $R_{100b}$ – result of 100 m bounded run.*

At the end of the preliminary basic preparation stage, the mathematical model of the result dependence on 400 m hurdles has the following form (formula 7):

$$W_{400\,w/h}=3{,}782xR_{400}+8{,}02xR_{100b}+2{,}09xR_{200}-0{,}46xR_{100}-0{,}27xR_{20b}+0{,}93xR_{60}+3{,}05xR_{30}+0{,}07xJ_u-0{,}17xJ_5-0{,}14xJ_s, \quad (7)$$

*where $W_{400\,w/h}$ – 400m hurdling result; $R_{400}$ – result of a flat race on 400 m from a crouch start; $R_{100b}$ – result of 100 m bounded run; $R_{200}$ – result of a flat race on 200 m from a crouch start; $R_{100}$ – result of 100 m running from a crouch start; $R_{20b}$ – bounded run 20 m on one leg; $R_{60}$ – result of 60 m running from a crouch start; $R_{30}$ – result of 30 m running from a crouch start; $J_u$ – result of jumping up according to Abalakov; $J_5$ – result of a five-fold jump from the spot; $J_s$ – standing long jump.*

The analysis of the results shows that the most important factors in achieving the result of 400 m hurdles is:

1. result of 100 m bounded run – 42,3%;
2. result of a flat race on 400 m from a crouch start – 19,9%
3. result of 30 m running from a crouch start – 16,1%.

The results of the inverse stepwise regression equation determine the three most influential factors (formula 8):

$$W_{400\ w/h}=10{,}45xR_{400}+8{,}52xR_{100b}+4{,}77xR_{30}, \quad (8)$$

*where $W_{400\ w/h}$ – 400 m hurdling result; $R_{400}$ – result of a flat race on 400 m from a crouch start; $R_{100b}$ – result of 100 m bounded run; $R_{30}$ – result of 30 m running from a crouch start.*

The level of technical readiness is the basis for achieving a sporting result. All elements of the technique of barrier running have a significant role in achieving a sporting result. However, some elements of technology play a leading role, while others complement. In our studies, the task was to determine the leading factors of the barrier running technique and the dynamics of their changes under the influence of the training stage of preliminary basic training. According to the results of the correlation analysis, 14 elements of the barrier running technique were selected.

The equation of multiple regression determined the level of significance of each element of the technique in achieving a sporting result in the 400 m hurdles (formula 9):

$$W_{400\ w/h}=4{,}79xW_{202}+3{,}1xW_{201}+2{,}21xTC-1{,}75xV_{br}-$$
$$-1{,}68xV_{st}+0{,}043xW_{rt}+0{,}14xW_{st}-0{,}47xT_{rb}-$$
$$-0{,}12xT_{ls}+0{,}019xCCG+0{,}08xL_{at}+0{,}07xL_{i}+0{,}036xL_{ln}, \quad (9)$$

*where $W_{400\ w/h}$ – 400 m hurdling result; $W_{202}$ – run time of the second 200 m hurdles; $W_{201}$ – run time of the first 200 m hurdles; TC – technical coefficient; $V_{br}$ – barrier step speed; $V_{st}$ – start run speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; $T_{rb}$ – distance to the repulsive barrier; $T_{ls}$ – distance from the barrier to the landing site behind the barrier; CCG – common center of gravity over the barrier; $L_{at}$ – angle of attack of the barrier; $L_i$ – angle of inclination above the barrier; $L_{ln}$ – torso angle when landing behind the barrier.*

The analysis of the whole mathematical model of the dependence of the sporting result on various technical elements determined the contribution level of each factor, among which the most important factors are indicators: running time of the second 200 m distance – 32,3%, running time of the first 200 m distance – 20,3%, skill ratio – 14,9%.

The equation of stepwise inverse regression determines in the final model five significant factors (formula 10):

$$W_{400\ w/h}=3{,}79xW_{202}+3{,}18xW_{201}-2{,}75xTC+$$
$$+1{,}25xV_{br}-1{,}61xV_{rs}, \quad (10)$$

*where $W_{400\ w/h}$ – 400m hurdling result; $W_{202}$ – run time of the second 200 m hurdles; $W_{201}$ – run time of the first 200 m hurdles; TC – technical coefficient; $V_{br}$ – barrier step speed; $V_{rs}$ – running step speed.*

At the end of the preliminary basic training phase of applying the multiple step-by-step regression equation, the result of the 400 m hurdles depends on the level of technical readiness in this form (formula 11):

$$W_{400\ w/h}=4{,}295xW_{202}+7{,}065xW_{201}+1{,}753xTC-1{,}623xV_{br}-$$
$$-1{,}81xV_{rs}+0{,}958xV_{st}+0{,}721xW_{rt}-0{,}651xW_{st}+0{,}743xT_{rb}+0{,}093x$$
$$xT_{ls}+0{,}872xCCG+0{,}177xL_{at}+0{,}131xL_{i}+0{,}113xL_{ln}, \quad (11)$$

*where $W_{400\ w/h}$ – 400m hurdling result; $W_{202}$ – run time of the second 200 m hurdles; $W_{201}$ – run time of the first 200 m hurdles; TC – technical coefficient; $V_{br}$ – barrier step speed; $V_{rs}$ – running step speed; $V_{st}$ – start run speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; $T_{rb}$ – distance to the repulsive barrier; $T_{ls}$ – distance from the barrier to the landing site behind the barrier; CCG – common center of gravity over the barrier; $L_{at}$ – angle of attack of the barrier; $L_i$ – angle of inclination above the barrier; $L_{ln}$ – torso angle when landing behind the barrier.*

The mathematical model at the end of the preliminary basic training stage significantly changed the significance of individual elements of the technique in achieving the result. The most factors: 1 – 30,8% and 2 – 29,8%. This confirms the equations stepwise inverse regression, in which there are only two of the most fundamental factors (formula 12):

$$W_{400\ w/h}=10{,}45xW_{202}+8{,}52xW_{201}, \quad (12)$$

*where $W_{400\ w/h}$ – 400 m hurdling result; $W_{202}$ – run time of the second 200 m hurdles; $W_{201}$ – run time of the first 200 m hurdles.*

The barrier step speed is one of the important elements of the barrier running technique. The speed of the barrier step is determined by the ratio of the length of the distance from the place of repulsion to the place of landing behind the barrier to the time from the support to the support. In our studies, the length of the barrier step is 3,47 m and the speed of overcoming the barrier is 5 $m \cdot s^{-1}$, that is, the speed of the barrier step is 6,54 $m \cdot s^{-1}$.

The use of the method of multiple regression allowed to establish the influence of each element of the technique on the speed of the barrier step (formula 13):

$$V_{br}=2{,}21xW_{rt}+4{,}79xW_{st}+1{,}75xT_{rb}-1{,}17xT_{ls}-$$
$$-0{,}96xL_{at}+0{,}75xCCG+0{,}36xL_{i}+0{,}08xL_{ln}, \quad (13)$$

*where $V_{br}$ – barrier step speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; $T_{rb}$ – distance to the repulsive barrier; $T_{ls}$ – distance from the barrier to the landing site behind the barrier; CCG – common center of gravity over the barrier; $L_i$ – angle of inclination above the barrier; $L_{ln}$ – torso angle when landing behind the barrier.*

Analysis of the mathematical equation shows that the most significant factors in overcoming the barrier are the support time when pushing the barrier ($W_{rt}$=39,7%) and the support time when landing behind the barrier ($W_{st}$=18,3%).

Inverse step-by-step regression determines three influential factors for increasing the speed of the barrier step (formula 14):

$$V_{br}=2{,}47xW_{rt}+4{,}74xW_{st}+1{,}82xT_{rb}, \quad (14)$$

*where $V_{br}$ – barrier step speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; $T_{rb}$ – distance to the repulsive barrier.*

At the end of the pre-basic training phase, the influence of each factor on the level of the barrier rate has changed slightly (formula 15):

$$V_{br}=2,79xW_{rt}+3,69xW_{st}-1,21xT_{rb}-0,97xT_{ls}-$$
$$-0,97xL_{at}+2,68xCCG+0,88xL_{i}+0,27xL_{ln}, \quad (15)$$

*where $V_{br}$ – barrier step speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; $T_{rb}$ – distance to the repulsive barrier; $T_{ls}$ – distance from the barrier to the landing site behind the barrier; $L_{at}$ – angle of attack of the barrier; CCG – common center of gravity over the barrier; $L_{i}$ – angle of inclination above the barrier; $L_{ln}$ – torso angle when landing behind the barrier.*

The most significant factors in achieving a competitive result in 400 m hurdles running is the support time when landing behind the barrier – 39,7%, the repulsion time when the barrier is attacked – 18,3% and the distance of repulsion to the barrier. The model of inverse step-by-step regression determines three reliable factors (formula 16):

$$V_{br}=2,009xW_{rt}+2,739xW_{st}+1,98xCCG, \quad (16)$$

*where $V_{br}$ – barrier step speed; $W_{rt}$ – repulsion time when barrier is attacked; $W_{st}$ – support time when landing behind the barrier; CCG – common center of gravity over the barrier.*

The obtained results contributed to the improvement of technical readiness indicators, which contributed to the improvement of the result of the 400 m hurdles run.

Thus, the results of the study show that the inclusion in the training process of interval hypoxic training contributed to a more significant increase in the anaerobic performance of 400 m hurdles runners.

## Conclusions / Discussion

Studies have shown that the achievement of sports results is possible only with a harmonious relationship of all aspects of athletes' preparedness.

This scientific position is particularly important in the preparation of 400 m hurdles runners, since the 400 m run, and especially the hurdles, is one of the hardest sports that runs under conditions of prolonged exposure to hypoxia.

The materials of the study indicate the need for hypoxic training, since increasing adaptability to hypoxia is the main mechanism for improving athletic performance in the 400 m hurdles.

The research results deepen the scientific data on the features of adaptation mechanisms to this type of competitive activity.

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