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original article

Spatio-temporal characteristics of hurdle runs and ergometric tests during athletic preparation

Características espaço-temporais de corridas com obstáculo e testes ergométricos durante a preparação no atletismo

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Abstract – The main goal of this study was to assess the appropriateness of both ergometric and modified hurdles tests for an annual cycle of hurdlers who were working on mastering the 400 m distance. Nine Polish hurdlers (personal best: 54.46±2.16 s, age: 20.67±1.87 years) were chosen as the research participants. In each of two mastering periods in the research, an ergometric test and a specific test were implemented during a hurdle run. In February, an interval ergometric test (5×6 s) and an interval hurdle test (IHT) were performed. Additionally, in May, a classic Wingate test and a 200 m hurdle run were introduced. With regard to the ergometric tests, we assessed the following measurements: maximum power (P_{max}) and mean power (P_x) reached in five repetitions as well as total work (W_{total}) performed in five attempts. The Mann-Whitney test was used to distinguish between the athletic test results obtained in the preparation period outlined above and those obtained in the first period. Lactate (LA) concentrations were assessed with the Chi-square test. Moreover, Spearman's rank correlation coefficients were used in the analysis. The achieved study results indicate the lack of significant differentiation of the ergometric test parameters ($p \geq 0.05$). The spatial structure of both specific tests (5×2 H v. 200 m H) was similar given that the first and the second parts of both hurdle races and the number of steps taken were similar. The basic parameters of the ergometric tests did not exhibit any relationship with the recommended record time achieved for the 400 m hurdle run.

Key words: Athletic training; Ergometric tests; Hurdle run.

Resumo – *O objetivo deste estudo foi avaliar a idoneidade de seleção dos testes ergométricos e testes modificados de corridas com barreiras ao longo do ciclo anual de treinamento dos atletas na distância de 400m. Participaram do estudo nove atletas poloneses (melhor resultado: 54,46±2,16s, idade: 20,67±1.87 anos). Em duas temporadas de treinamento foram realizados dois testes: ergométrico e especial (=na corrida com barreiras). Em fevereiro foi efetuado o teste ergonómico em intervalos (95x6s) e o teste com barreiras Rest com intervalos (IHT). Em maio foi efetuado o teste clássico de 30 s Wingate e uma corrida de 200m com barreiras (200mH). Nas corridas com barreiras foram considerados os parâmetros de tempo, potência máxima (P_{max}), potência média (P_x) e trabalho total (W_{total}). Para avaliar as diferenças entre os resultados dos testes numa temporada foi aplicado o teste de Mann-Whithney. As diferenças de concentração do lactato (LA) foram avaliadas com o teste Chi-square. Na análise foram considerados também os coeficientes de correlação de postos de Spearman. Os resultados dos estudos demostram a ausência de diferenças pertinentes nos parâmetros dos testes ergométricos ($p \geq 0,05$). A estrutura espacial de ambos os testes especiais (5x2H vs. 200mH) foi semelhante: na primeira e segunda parte de ambas as corridas foi efetuado o número parecido dos passos. Os parâmetros essenciais dos testes ergométricos (P_{max}, P_x, W_{total}) não demostraram relações importantes com o resultado recorde na corrida de 400m com barreiras. A análise demostrou a possibilidade de utilização seletiva dos testes ergométricos na avaliação do grau de preparação dos atletas para a distância de 400m com barreiras.*

Palavras-chave: *Corrida com barreira; Desempenho atlético; Teste ergométrico; Treinamento de atletas.*

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INTRODUCTION

The 400 m hurdle race is one of the few athletic events that exclusively takes place in a stadium. Training and competing in a stadium is possible for only half of the training year (from April to September) in the majority of European countries. Autumn and winter training for the 400 m hurdle race takes place indoors.

The climate and specific nature of this track event force coaches to identify appropriate exercises and organize proper and reliable control systems. The forms and methods of indoor training for 400 m hurdlers are presented in works including those by McFarlane[1] and Iskra and Coh[2].

On the basis of proven training concepts, coaches utilize a small number of special test models that employ interval hurdle runs: 'shuttle runs' or 'turnabouts'[1].

In the winter, an athlete is often not prepared to run hurdles at maximum (testing) speed. In this period, ergometric tests are a form of laboratory test that assesses preparation based on glycolytic changes. Apart from the classic Wingate test, other interval tests using an ergometer are also possible[3-5]. The efficacy of their use has been assessed in previous publications[6].

The objective of this article was to evaluate the possible uses for ergometric tests during hurdlers' annual cycle of preparation for the 400 m race. The following research questions were asked:

1) Is it reasonable to use ergometric tests to assess hurdlers who are training for the 400 m race?
2) Is it useful to replace interval tests (runs and ergometric tests) with continuous tests?
3) Which of the tests exhibit the strongest relationship with hurdlers' athletic abilities?

METHODOLOGICAL PROCEDURES

Material

The research participants were nine Polish hurdlers who specialized in the 400 m hurdle (personal best 54.46±2.16 s, age 20.67±1.78, stature 179.89±3.72 cm, body mass 74.69±5.72 kg). The group included one participant in the Olympic Games (2012 London) and two representatives of Poland in junior age categories. The study was approved by the Opole Bioethics Committee (Decision/131 November 2005).

Methods

The hurdlers' exercise capacity was evaluated using specific tests (2 hurdle runs) and non-specific tests (two ergometric tests).

Tests were performed for two training periods: during the general preparation period (GPP) in February and during the specific preparation period (SPP) in May, which is the period directly before competitions.

In the GPP, interval-based tests (an interval hurdle test [IHT] and an interval ergometric test [5 × 6 s]) were conducted.

In the SPP, a 200 m hurdle run and a classic (Wingate) ergometric test were conducted.

Characteristics of tests

- **Interval hurdle run/test (IHT)**

For a shuttle run, an athlete covers five times the distance of 35 m with two hurdles at a height of 91 cm. For this study, the distance from the start line to the first hurdle and from the second hurdle to the finish line was 8.75 m, and the distance between hurdles was 17.5 m. Each break between repetitions was the difference between 30 s and the time required to run the given distance; on average, the athletes had approximately 24 s of rest. The run times were measured using photocells. The runs took place on an indoor athletic track.

The following parameters were used in the work:

- time of the run (at the end of 5 sections);
- times of the first and second parts of the run (sections 1 + 2 and 4 + 5, respectively);
- number of steps taken between hurdles;
- number of steps in the first (distances no. 1 and 2) and second parts (distances no. 4 and 5) of the run;
- lactate concentration after the effort (LA_{IHT}).

The run was organized on the basis of previous works[1,6-8] and included the authors' modifications concerning the aims of the work.

- **Interval ergometric test (5 × 6 s)**

The test was performed using a Monark 894E ergometer in accordance with the rules specified by Fitzsimans et al.[4] and accepted by sport authorities[5]. Athletes performed for 6 s of maximum effort 5 times with a 24 s interval between repetitions. The following parameters were used in the analysis:

- total work performed for 5 efforts (W_{total});
- maximum power (mean of five repetitions, P_{max});
- mean power (mean of five repetitions, P_x);
- lactate concentration after the effort (LA_{5x6s}; measured 4 min. after the effort).

- **200 m hurdle run (200H Run)**

The run through 10 hurdles at a height of 91 cm was performed in accordance with the following rules: the distance to the first hurdle was 20 m, the distance between each hurdle was 17.5 m (similar to the hurdles in the indoor run), and the distance from the last hurdle to the finish line was 22.50 m. The runs were conducted on the Tartan track of the athletic stadium. The choice of the aforementioned rules was determined by the period of preparation and the specific nature of the 400 m hurdle race. Similar run parameters were presented in previous publications[1,8]. The following parameters were used in the work:

- time of the 200H Run (t_{200H});
- time of the first (hurdles no. 1–5) and second (hurdles no. 6–10) parts of the run (t_{1-5H}, t_{6-10H}, respectively);
- number of steps taken between hurdles (n);
- number of steps in the first and second parts of the run (n_{1-5H}, n_{6-10H}, respectively)
- lactate concentration in blood (LA_{200H}).

- **30 s ergometric (Wingate) test**

The Wingate anaerobic capacity test with a duration of 30 s was performed using a Monark 894E ergometer with MCE v.5.1 software. The test was performed according to the standard procedure[9].

The following parameters were used in the analysis:

- total work (W_{total});
- average and maximum power (P_x, P_{max});
- lactate concentration 4 min. after the effort ($LA_{Wingate}$);

In the final analysis, we used the personal best results in 400 m hurdle competitions (between July and August).

Analytical procedure

Fasting blood samples were collected 5 minutes after the effort. Blood plasma was separated according to routine procedures and either processed immediately or maintained at -80° C until the analysis.

Plasma lactate (LA) concentrations were measured using the methods of Shimojo et al.[10] with commercially available kits (BioMérieux).

Statistical analysis

The data are presented as means, standard deviations (SD), maximums (Max) and minimums (Min). Differences between the groups were identified using the non-parametric Wilcoxon Z test. Differences between LA concentrations in the 4 types of effort were assessed using the Friedman ANOVA test. The significance level was set at $p \leq 0.05$. In addition, Spearman's rank order correlation coefficients were computed to demonstrate the relationships between the variables. All statistical analyses were performed using Statistica 6.0 (StatSoft, Inc.) software.

RESULTS

Selected ergometric test parameters (5 × 6 s and 30 s/Wingate) are presented in Table 1.

The results of the Wilcoxon Z test demonstrate the lack of statistically important differences between the total work, average power and maximum power achieved in both tests organized by training period.

Table 1. Primary parameters of the ergometric test.

Test	Parameter	$\bar{x} \pm SD$	Min.-Max.	Wilcoxon test (Z)
5 × 6 s	$\sum W$ (J/kg)	262.10 ± 15.01	238.2 - 278.7	0.67 (p=0.50)
Wingate	W (J/kg)	270.00 ± 17.16	245.50 - 290.8	
5 × 6 s	$P_{\bar{x}}$(W/kg)	8.74 ± 0.50	7.94 - 9.29	0.67 (p=0.50)
Wingate		9.00 ± 0.57	8.18 - 9.69	
5 × 6 s	P_{max} (W/kg)	11.36 ± 0.38	10.64 - 11.89	1.33 (p=0.18)
Wingate		11.80 ± 0.77	10.71 – 12.59	

The results of the hurdle run tests and the numbers of steps in the first and second parts of the run are presented in Table 2. No significant relationships were observed between the numbers of steps in the two parts of the runs performed in February and in May ($p \geq 0.05$).

Table 2. Results of the hurdle run tests and numbers of steps in the two parts of the run tests.

Test	Parameter/Test	$\bar{x} \pm SD$	Min.- Max.
5 × 2 H	Time of run (s) Number of steps (s)	34.90±1.28 75.89±2.31	33.23–36.63 71–79
200 m H	Time of run (s) Number of steps (s)	27.02±1.95 78.67±3.94	24.37–30.98 73–82
First part of run	5 × 2 H 200 m H	29.78 ± 0.67 30.0 ± 2.00	28–30* 28–32
Second part of run	5 × 2 H 200 m H	31.78 ± 2.17 31.56 ± 2.40	29–35** 28–34

Wilcoxon test (Z): * 0.34 (p=0.73); ** 0.42 (p=0.67)

The lactate concentration (LA) levels after the tests are presented in Table 3. Statistically significant differences were observed with the Chi-square test (9.66, p=0.0216).

The correlation coefficients between selected parameters of the 4 tests and the 400 m run are presented in Table 4. The work and power measured by the ergometric tests had no significant association with the hurdlers' athletic abilities. Statistically important relationships were observed with regard to 3 of the run tests performed in 3 training periods.

The LA values for all the tests are presented in Table 5. Significant relationships were noted only in the run tests.

Table 3. Lactate concentration results from the 4 tests (in mmol/l).

Test	$\bar{x}$ ± SD	Min.-Max.	Freidman ANOVA
5 × 6 s	13.36 ± 1.26	10.83–14.78	Chi square=9.66, p=0.0216
5 × 2 H	13.10 ± 0.81	11.90–14.45	
Wingate (30 s)	13.73 ± 1.19	10.85–14.68	
200 m H	13.87 ± 0.92	11.66–14.67	

Table 4. Spearman's rank correlation coefficients between the run tests and selected parameters.

Test	Parameter	400 m H (s)	5 x 2 H (s)	200 m H (s)
400 m H	Personal best	-	0.90*	0.95*
5 × 6 s	Total work Average power	- 0.16 - 0.18	- 0.25 - 0.25	- 0.27 - 0.27
Wingate 30 s	Total work Average power	- 0.14 - 0.31	- 0.03 - 0.29	0.03 - 0.25
5 × 2 H	Time of run Number of steps	0.90* 0.55	- 0.55	0.88* 0.41
200 m H	Time of run Number of steps	0.95* 0.50	0.88* 0.93*	- 0.96*

*p≤0.01

Table 5. Spearman's rank correlation coefficients of the LA concentrations in various 400 m hurdle run tests.

No.	Test	1	2	3	4
1.	5 × 6 s	-	0.17	0.18	0.02
2.	30 s Wingate	0.17	-	0.50	0.37
3.	5 × 2 H	0.18	0.50	-	0.85*
4.	200 m H	0.02	0.37	0.85*	-

*p≤0.01

DISCUSSION

The effort in the 400 m hurdle race is based on anaerobic lactic acid changes[11]. The research performed in sprint runners suggests that anaerobic processes range from 55% to 87% during the Wingate ergometric test. Most authors believe there is a relationship between lactate concentration and the maximum power measured by the Wingate test[12]. The relevance of ergometric tests to sport was confirmed in numerous publications[13-17].

Previous research performed among top Polish hurdlers at 110 m and 400 m demonstrated a significant relationship among maximum power and total work and hurdlers' athletic abilities. With regard to 400 m hurdlers, these values were r=-0.49 and -0.61 (p≤0.01), respectively[18].

Another argument for the use of ergometric tests in preparation for the 400 m hurdles is the specific nature of this event, given that 400 m hurdle races can only occur in a stadium from October to April. In light of central European weather conditions, it is not possible to perform specialist training in a stadium in autumn and winter (snow, low temperatures).

During the preparation period, interval hurdle runs are the primary form of special training[1,6,19]. Together with non-specific (ergometric) tests, interval hurdle runs can be an important part of the training for 400 m hurdlers[1,8].

The analysis of the ergometric test results (Wingate and 5 × 6 s tests) did not reveal any differences with regard to total work (W_{total}) or power (average power and maximum power; Pxx and P_{max}). The results achieved by the group studied do not differ from the results achieved by the hurdlers who participated in the research, and the results differ only slightly from the results of research on the Polish 400 m hurdle team [2,18].

The Wingate test yielded the following results: W_{total}: 281.5±17.6 (J/kg) and 270.0±17.1, and P_{max} 11.7±0.8 and 11.8±0.8 W/kg. The hurdlers' high anaerobic capacity was confirmed using the results of research performed by other authors[14,15].

The lack of differences in the basic ergometric test (Wingate and 5 × 6 s) parameters is an important piece of information with regard to the complementary nature of non-specific hurdler preparation tests.

Run tests that are strictly connected with the preparation period are another example of an attempt to identify specific (=hurdles) preparation control tests that are relevant to the event (400 m H)[7,8,18,20].

The standardized conditions in which the test was performed make it possible to compare the run times in the first and second parts of the distance. In both cases, no statistically important differences were noted (Table 2). This serves to indicate the proper choice of tests and the continuity of annually controlling the preparation of 400 m hurdlers.

However, the most important aim of this research was to evaluate the simultaneous use of specific (run) and ergometric tests. This concerned both single efforts (200 m H, Wingate test) and interval-based efforts (5 × 2 H run, 5 × 6 s test).

One criterion for evaluating anaerobic effort is evaluating post-effort concentrations of lactate in the blood (LA_{max}). Denis et al.[21] and Granier et al.[12] reported a significant correlation between peak power during the Wingate test and maximum lactate concentration (0.87 and 0.75, respectively). The research conducted among top Polish hurdlers from 1994 to 2000 demonstrated that lactate concentrations during run tests performed in the preparation period were 14.95±0.59 mmol/l (per 300 m)[22].

The maximum lactate concentrations after sprinters' and hurdlers' starting efforts were slightly higher (from 16 to greater than 20 mmol/l)[23,24]. However, in the research conducted by Hautier et al.[25] using a group of top Cameroonian sprinters, the post-effort LA concentration after a 200 m run was only 10.3 mmol/l.

In the research conducted by Hill[26] using 400 m runners (university level), the lactate concentrations obtained were similar to those obtained for the group of runners in this study (14.7±2.2 mmol/l). The study by Klapcinska et al.[22] assessed only Polish 400 m national hurdlers, whereas the research by Hill[26] evaluated only medium-class runners. This may explain the differences between the SDs (0.59 and 2.2 mmol/l, respectively).

In this study, the post-effort lactate concentrations were 13.10-13.87 mmol/l and exhibited important significant differences (Chi-square=9.66, p=0.0216). High LA values, which reflect the effort exerted in prolonged sprints, and the lack of significant differences suggest that these tests are ideal anaerobic tests for training 400 m hurdlers.

Further analysis concerned the relationships between selected test parameters and the hurdlers' athletic abilities (personal bests in the year preceding the tests).

Significant correlation coefficients (p≤0.01) were noted for only the times of the 200 m hurdle run and the 5 × 2H interval run (r=0.95 and r=0.90, respectively). A direct relationship was lacking between the ergometric test parameters and the primary parameters (number of steps and time of run) of the hurdle run (Table 4). For the training control process, a significant relationship between the times of hurdle runs performed during the general preparation period (5 × 2H) and during the period preceding competitions was noted (200 m H, r=0.88, p≤0.01).

The differences between the event-specific (hurdle runs) and non-specific tests (ergometric tests) were emphasized by the Spearman's correlation analyses of all of the post-effort LA values. A statistically significant relationship (r=0.85, p≤0.01) was noted only between two hurdle runs (Table 5).

CONCLUSIONS

The simultaneous use of run tests and ergometric tests in the control of 400 m hurdler preparation is reasonable, but some minor limitations should be noted. Ergometric tests and hurdle runs require similar anaerobic effort; however, the non-specific nature of movement is an obstacle to the clear prediction of 400 m hurdle race results.

Ergometric and run test parameters were assessed using the continuous method (the Wingate test and the 200 m hurdle run, respectively) and the interval method (the 5 × 6 s test and the 5 × 2H run, respectively), indicating a high degree of similarity between the aforementioned efforts.

No apparent differences were noted between the primary test parameters (total work and maximum power) for both the ergometric tests as well as the run tests (there were similar times for the first and second parts of the distance in both hurdle runs).

The prediction of 400 m hurdle race results can be based exclusively on hurdle run results.

This study revealed that winter training sessions for the 400 m hurdles are (in typical European conditions) complicated. Coaches must change the typical forms of training (runs on the outdoor tracks) or atypical efforts (interval runs and ergometric tests).

With regard to 400 m hurdle runs, training requires the use of many non-specific (in winter conditions) and specific (mainly hurdle runs) forms of control. Our results indicate that ergometric tests can properly measure anaerobic capacity but are not useful for special preparation processes.

Our analysis revealed that we can compare only both running tests and (separately) both ergometric tests. In the search for correlations between running tests and unspecific (according to hurdle runs) ergometric efforts, coaches should be careful.

A special preparation process that is typical for the event concerned can be evaluated on the basis of elaborated continuous (200 m H) and interval run tests (5 × 2H). There is a high degree of correlation between 400 m hurdle run times and the results of these tests given that the durations were similar to those in competition conditions in all training periods (winter, spring). Ergometric tests are a useful part of the preparation process with regard to anaerobic capacity.

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