THE INFLUENCE SOMATIC TRAITS AND MOTOR FITNESS ON HURDLE RACE RESULTS BY UNTRAINED BOYS AGED 11-15

by

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The goal of this paper was aimed at evaluation of relationships between chosen efficiency variables and somatic constitution indexes with results of a hurdle race by untrained boys at the age of 11-15.

Continuous measurements, carried out between 1994-1998, were preceded by pilot researches (1993-1994) aimed at determining the principles of the run (distance between hurdles, height of hurdles) for particular age categories.

The research project included 42 boys, pupils of primary school No. 15 in Ruda Śląska. Two variations of hurdle race were adopted, with 3- and 4-stride rhythm between hurdles, along with battery of efficiency tests directed according to specificity of a discipline (20-30 m, 40-60 m, and 120-180 m runs, standing triple-jump, counter-movement jump, overhead medicine ball throw, forward bend and stepping onto a ladder). On the basis of the above mentioned tests, the following factors were calculated:

- level of the technique of hurdle race,
- co-ordination efficiency,
- speed endurance,
- flexibility of hip joint.

For the analysis also used were variables of somatic constitution (body height and mass, length of lower limbs) to calculate Rohrer factor.

Gathered data has been elaborated statistically to define normality of distribution of the variables under research, differences between results in successive years and differences between separated sub-groups (with a t-test, for dependent and independent variables). Interdependencies of results of a hurdle race with chosen motor fitness variables were evaluated by means of Pearson simple correlation coefficient.

Lack of hurdle race velocity changes during the 5 year period of tests confirmed the aptness of every year modification of principles of the run according to changing body height. In most of the tests a systematic increase in results was observed. Between the age of 11 and 12 only results of the forward bend decreased, while endurance, flexibility and co-ordination did not show any essential changes. Hurdling efficiency, measured with a technique level index also decreased.

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For most variables the dynamics of changes reached the highest level between age 13 and 15; it was probably due to pubescence development transformations.

Analysis of correlation showed that a hurdle race in groups of non-trained boys is a discipline with mainly energetic, alactacid anaerobic basis. Most distinct connections were observed between results of hurdle race with 3-stride rhythm and running tests, standing triple-jump and counter-movement jump.

The above conclusion was confirmed by multiple regression equations. Among variables best explaining results of a hurdle race are: three runs (20-30 m, 40-60 m, and 120-180 m), standing triple jump and technique level index.

Key words: Leigh athletic, competitive youth sports, selection

Introduction

Research evaluating the factors determining the results of hurdle races in groups of unexperienced athletes are rare, presumably due to difficulties caused by selection of apt principles (rules) of these disciplines and complex technical structure of a hurdle race. Hitherto realised trials of analysis of interdependencies between motor fitness test results and hurdle race results by children and youth were carried out by beginning athletes, tested in standard start conditions (Herm & Gerroldt 1980, Pierewiercew et al. 1985, Tabacznik et al. 1985).

Doan and Siris (1974) examined relationships of chosen motor fitness tests with results of hurdle races in groups of different level of advancement. Among 13-year old hurdles, most distinct interdependency was that between hurdle race results with tests of running speed, long jump and standing triple jump. Herm and Gerroldt (1980), analysing a group of 124 girls and boys at the age of 10-12, discovered a interdependence between length of lower limbs and length of a running stride with a choice of 3- or 4-stride rhythm. Longitudinal research of children and youth in track and fields speed disciplines were carried out mainly in sprints (Siris and al. 1983, Alończyk et al. 1997).

In children's hurdle racing an exceptional research project was realised by Tabacznik and Pierewiercew (Pierewiercew et al. 1985, Tabacznik et al. 1985). During a 5-year period both these authors analysed development of motor abilities and co-ordination by beginning hurdlers at the age of 10-15 (n=21).

In above mentioned research a hurdle race was performed according to the rules of national track and field associations concerning the youngest age

categories. However, rules concerning, among other things, the height of a hurdle and distance between hurdles are not well suited for untrained children (Etzold 1981, McFarlane 1991). It results from ignoring the hurdle race as a form of exercises in school physical education programs. In many countries this discipline is perceived as a proper means of improving fitness and co-ordination (Spagolla & Bortoli 1985, Torim 1991, Iskra & Walaszczyk 1994). The appropriate methods of exercising and principles matching the level of trainees enable to realise successfully simple forms of hurdle race with children at the age of 9-10 (Medler & Katzenbogner 1990, Pilva 1995).

For research on a hurdle race by untrained children and youth, there is a neccessity of specific way of handling of this discipline, different from competitive sport approaches. A hurdle race in a school physical education program is similar to the original form of this discipline, where it is performed as a specific "obstacle track" passed with a maximum velocity at 3-stride rhythm. It was confirmed by observation of McFarlane, who stated that "hurdle race is in fact a perfect obstacle sprint" (McFarlane 1991, p. 73). A choice of non-trained children and youth enables to evaluate the associations of selected somatic and motor variables with results of a hurdle race without necessity to allow for interference of training process. Observations made in groups of beginning athletes (even children at the age of 10-12) took into account a preliminary selection, teaching of a movement technique and goal-oriented formation of motor abilities and co-ordination.

Aim of research

In his previous papers, one of the authors presented the results of a one-year research which attempted the evaluation of relationships between results of a run with low obstacles, motor fitness and chosen variables of somatic constitution by 10-yearold children, as well as searching for optimum principles of this discipline for school population (Iskra 1996). The presented paper is aimed at determining fundamental hurdle race parameters for untrained boys at the age of 11-15. Researches were carried out continuously (repeated every year). Such a choice of research material enabled the determination of motor fitness and somatic traits for hurdle race results in respect to developmental

transformations. Obtained data will serve also as a basis for more general characteristics of hurdle race by boys of 10-15 as an efficient means of physical fitness development, which could be useful in selection of boys for this discipline.

Material and methods

Research schedule

In 1993, during physical education classes, exercises were performed with the use of simple forms of hurdle races in determined rhythm (Iskra and Walaszczyk 1994). The lessons proved that there exists a possibility of using the hurdle races as an attractive exercise in physical education lessons. In 1994 pilot research was conducted, which enabled to specify hurdle race principles, necessary in planned continuous research (Iskra 1996). In 1994-1998 there was performed appropriate 5-year cycle of research.

Research material

Conclusions were based on results of continuous research of pupils of primary school No 15 in Ruda Śląska. In research 42 boys at the age of 11-15 took part.

From the whole group 2 groups were separated with different progress results in hurdle race. During the 5-years research cycle, in group A (n=21) an increase, and in group B (n=21) – a decrease in hurdle race velocity was observed. Taking Tabacznik et al. (1985) papers as a model, the whole period under research was divided into two equal sub-periods: age of 11-13, and 13-15.

Measuring tools

Principles of hurdle race for non-trained boys

To perform the research properly, it was necessary to define optimum principles of hurdle racing. Therefore, the authors resigned from adopting the rules of this discipline established for youngest age categories (Etzold 1981, McFarlane 1991).

Determining the hurdle race rules for untrained pupils, the following has been taken into account:

1. Safety and specificity of exercises: as in other works (Medler and Katzenbogner 1990, Pliva 1995), for boys at the age of 11 there were subsidiary cardboard hurdles adopted, and later youth hurdles manufactured by Polanik.
2. Hurdles were lower than those used in competition for given age categories. With respect to mean body height, distance between hurdles was adjusted for either 3- or 4-stride rhythm.

Table 1. Principles of a hurdle run for non-trained boys (own proposition)

Age	Distance (m)	Number of hurdles	Height of hurdles (cm)	Distance between hurdles		Distance to 1st hurdle
				Variant 1	Variant 2	
11	40	4	40[1)]	6,20[2)]	7,70[3)]	10,90[4)]
12	50	5	50	6,45	8,10	11,30
13	60	5	60	6,70	8,40	11,80
14	60	5	70	7,00	8,70	12,20
15	60	5	76	7,30	9,10	12,80

[1)] cardboard hurdles,
[2)] 4 x length of a running pace, where running pace length amounts to = 1,07 x body height,
[3)] 5 x length of a running pace,
[4)] 7 x length of a running pace.

Also adjusted were: length of the distance (40, 50 or 60 m), number of hurdles (4 or 5), height of the hurdles (40, 50, 60, 70 or 75 cm) and distance between hurdles (Schmolinsky 1981, Spagolla & Bortoli 1985). First option consisted in adopting a 3-stride rhythm between hurdles (distance was determined according to equation: 4 x length of the running stride – Artiuszenko & Beglecow 1975). The length of a running stride was calculated from formula 1,05 x mean body height for given age category (Leierer 1979). In the second option (4-stride rhythm), distance between hurdles amounted to 5 x hurdle stride. In both variations of the distance to the first hurdle equalled to 7 x running stride. Principles of both run options have been presented in Table 1.

The start to all runs was individual, in standing position, and time of a run was measured from the moment of making the first movement. Such procedure eliminated difficulties related with performing the low start and differences

resulting from reaction time to the start signal. In successive trials every year, 2 tests were performed and the better results were included to statistical analysis.

Selection of motor fitness tests and somatic traits

Selection of the tests of directed efficiency of hurdle racers was accomplished on the basis of two criterions determined in previous experiments (Iskra 1996, 1999):

- compatibility of the test (with regard to the form of the movement or specificity of the effort) with hurdle race,
- possibility of adaptation of these tests to the needs of school physical education.

Therefore, the following tests were carried out:

1. Run of 20, 25 m (age of 11 and 12) or 30 m, evaluating the sprint start (Brejcha 1985, Battisti et al. 1990, Platonow & Zaporozanow 1990, Delecluse et al. 1992, D'Aprile 1993).
2. Run of 40 m (age of 11), 50 m (age of 12) or 60 m (age of 13-15), were used as maximum speed tests, as well as maximum anaerobic power.
3. Run of 120 m (age of 11), 150 m (age of 12) or 180 m (age of 13-15), to evaluate speed endurance; this also allowed to evaluate the anaerobic capacity.
4. Standing triple jump; at the age of 11 first take-off was made with a split legi position (Bowerman & Freeman 1991).
5. Vertical jump.
6. Overhead medicine ball throw backwards (3 kg); three trials were performed with the best result taken to analysis.
7. Medicine ball throw (3 kg) two-hand forwards; this tests were aimed at evaluation of explosive strength.
8. Forward bend in sitting position, flexibility test; to obtain only positive values, as a "zero point" was adopted a point lying at a distance of 20 cm.
9. Stepping with lead leg to a ladder – flexibility test of a the hip joint in sagittal plane, as in Wright's test (1974).

Test results enabled to calculate following indexes:

- speed endurance index: VEI = ($V_{120\text{-}180}$: $V_{40\text{-}60}$) x 100% (according to Cempel 1971; V – velocity of run),

- technique level index: TLI = [($V_{40\text{-}60}$ − $V_{40\text{-}60\ hurdles}$) / $V_{40\text{-}60\ hurdles}$] x 100% (according to Gorbienko & Smirnov 1980, McFarlane 1991),
- co-ordination efficiency index: CEI = (|$V_{40\text{-}60\ hurdles(I)}$ − $V_{40\text{-}60\ hurdles(II)}$|) x 100%, where 40-60 m hurdles (I) is a run in 3-stride rhythm, and 40-60 m hurdles (II) is a run in 4-stride rhythm.; this index should indirectly inform about level of co-ordination abilities,
- flexibility index of hip joint: FI = length of stride by ladder : length of lower limb.

During runs at distances of 20, 25 or 30 m strides were counted and on the basis of such calculations a mean length and frequency of strides determined (Siris et al. 1983). Choice of a test of start acceleration as a means of evaluation of pace length (Własow & Filin 1971) resulted from specificity of a hurdle race, where distance between hurdles is covered with slightly shortened pace.

During the hurdle races, the number of strides between hurdles were counted. These data were a basis for calculation of a percentage of subjects under research, which were able to maintain imposed rhythm of a run.

In the somatic constitution evaluation, following variables were taken into account: body height, lower limb length (B – sy), body mass and Rohrer index.

Calendar age was read from a table of decimal parts of a year (Jopkiewicz & Suliga 1995).

Statistical methods

Obtained data were an object of statistical analysis, where following values were calculated: mean value (x), standard deviation (SD) and variability coefficient (V). Results of all runs were expressed in velocity units (m/s), what enabled comparison of results of runs at various distances.

Normality of distribution of variables under research was determined with asymmetry assymetry (As) and kurtosis (Ku), as well as Kolmogorov-Smirnov test.

Significance of differences between mean results of all tests in successive years was evaluated with t-test for dependent variables. Differences of test results between groups showing progress and regress of results of hurdle race were evaluated with t-test for dependent variables.

Relationships of hurdle race results with motor fitness tests results and somatic traits were determined on the basis of Pearson's coefficient of correlation r.

Selection of variables from among listed items, which best explain results of a hurdle race, was made by construction of a multiple regression model according to Hellwig method (Hellwig 1970, Ryguła & Wyderka 1993). Calculations were performed with Statistica programme.

Results

Developmental changes of somatic traits, results of hurdle race and motor fitness tests

Fundamental somatic traits of researched subjects were compared with results of boys from urban population. Data obtained from lower limb length measurements were comparable with research results acquired by Żak and Sakowicz (1996: Table 2). The changes of Rohrer index (RI) indicated gradual slimming of a body. Slim constitution of a body was mainly characteristic for boys, which achieved better results in a hurdle race (Table 2). Well-marked changes of length parameters (body height and lower limb length) were a basis for every year, previously described modification of hurdle race rules. It was presumably due to these modifications that during 5-years cycle of research hurdle race results (in both variants) maintained nearly the same level. Velocity of a run in 3-stride rhythm amounted to 5.32 – 5.30 m/s (Table 3). Constancy of velocity developed by subjects confirmed a proper direction of changes of adopted rules of hurdle race, when a grade of difficulty increased in successive years of experiment. In the first year of researches, in both variants of hurdle race, boys at the age of 11 from the group B achieved better results than team from the group A. Till the age of 13 there were no differences observed in result levels in groups A and B. Only by boys at the age of 14-15 occurred statistically significant progress (group A) or regress (group B) of results of a hurdle race (Table 3).

Table 2. Characteristics of selected parameters of somatic constitution in successive years of researches

Parameter	Age	Whole (n = 42)	Group A (n = 21)	Group B (n = 21)
		x ± Sd	x ± Sd	x ± Sd
Body height (cm)	11	145,0 ± 5,61	146,23 ± 5,12	143,91 ± 5,96
	12	150,52 ± 5,93	152,34 ± 5,18	148,71 ± 6,18*
	13	157,10 ± 7,48	159,81 ± 6,97	154,38 ± 7,11*
	14	162,69 ± 8,04	165,87 ± 7,41	159,51 ± 7,52*
	15	170,08 ± 7,22	173,83 ± 5,69	167,78 ± 7,43*
Body mass (kg)	11	38,37 ± 7,70	38,01 ± 6,17	38,74 ± 9,13
	12	41,98 ± 8,51	42,43 ± 7,06	41,52 ± 9,90
	13	46,87 ± 10,06	47,52 ± 7,65	46,21 ± 12,17
	14	51,20 ± 10,96	52,46 ± 8,45	49,93 ± 13,09
	15	57,43 ± 12,07	59,09 ± 9,12	55,76 ± 14,49
Lower limb length (cm)	11	74,50 ± 3,28	75,45 ± 3,21	73,55 ± 3,13
	12	78,06 ± 3,62	79,15 ± 3,36	76,96 ± 3,61*
	13	80,98 ± 4,08	82,45 ± 3,83	79,50 ± 3,86*
	14	84,03 ± 4,15	85,31 ± 3,51	82,75 ± 4,41*
	15	88,74 ± 4,25	90,21 ± 4,08	87,27 ± 3,98*
Rohrer index	11	1,25 ± 0,16	1,21 ± 0,13	1,28 ± 0,18
	12	1,22 ± 0,16	1,19 ± 0,14	1,24 ± 0,19
	13	1,20 ± 0,17	1,16 ± 0,12	1,24 ± 0,19
	14	1,18 ± 0,16	1,14 ± 0,11	1,21 ± 0,19
	15	1,14 ± 0,16	1,12 ± 0,12	1,16 ± 0,20

Legend to a Table 2 and next:
- significance of differences between groups A and B: $p \leq 0,05$ (*), $p \leq 0,01$ (**), $p \leq 0,001$ (***)

During 5-years research period, the mean number of strides in runs with different distances between hurdles amounted to 3.17 – 3.29 (variant 1) and 3.99 – 4.33 (variant 2). Planned 3-stride rhythm (variant 1) on the whole distance or on its part realised 90,5% of boys, 4-stride one (variant 2) – 92,9% of boys. Maintaining the planned rhythm was easier in group A. In group B, especially at the age of 14-15, occurred increase in number of strides between hurdles comparing to previous years (Table 3).

Table 3. Characteristics of hurdle race results

Test / parameter	Age	Whole (n = 42)	Group A (n = 21)	Group B (n = 21)
		x ± Sd	x ± Sd	x ± Sd
Hurdle race in 3-pace rhythm (m/s)	11	5,33 ± 0,53	5,32 ± 0,54	5,34 ± 0,53
	12	5,33 ± 10,49	5,34 ± 0,41	5,33 ± 0,56
	13	5,35 ± 0,47	5,44 ± 0,51	5,26 ± 0,43
	14	5,32 ± 0,58	5,55 ± 0,60	5,09 ± 0,49**
	15	5,33 ± 0,63	5,70 ± 0,56	4,96 ± 0,47***
Hurdle race in 4-pace rhythm (m/s)	11	5,23 ± 0,57	5,19 ± 0,62	5,28 ± 0,53
	12	5,30 ± 0,51	5,33 ± 0,47	5,27 ± 0,56
	13	5,22 ± 0,42	5,31 ± 0,44	5,13 ± 0,37
	14	5,28 ± 0,55	5,49 ± 0,54	5,07 ± 0,48*
	15	5,26 ± 0,59	5,55 ± 0,54	4,97 ± 0,50***
Number of paces between hurdles (variant 1)	11	3,28 ± 0,39	3,19 ± 0,29	3,37 ± 0,46
	12	3,17 ± 0,31	3,04 ± 0,17	3,30 ± 0,37**
	13	3,19 ± 0,31	3,15 ± 0,29	3,23 ± 0,33
	14	3,29 ± 0,41	3,19 ± 0,35	3,39 ± 0,45
	15	3,27 ± 0,40	3,10 ± 0,23	3,44 ± 0,47**
Number of paces between hurdles (variant 2)	11	4,20 ± 0,35	4,16 ± 0,36	4,24 ± 0,35
	12	3,99 ± 0,36	3,95 ± 0,30	4,04 ± 0,41
	13	4,13 ± 0,38	4,04 ± 0,45	4,23 ± 0,28
	14	4,28 ± 0,38	4,18 ± 0,32	4,38 ± 0,42
	15	4,33 ± 0,43	4,14 ± 0,38	4,51 ± 0,41**
Co-ordination efficiency index (CEI) (%)	11	96,95 ± 2,52	96,54 ± 2,62	97,36 ± 2,40
	12	97,04 ± 1,96	96,90 ± 2,18	97,18 ± 1,76
	13	96,49 ± 2,12	96,02 ± 2,37	96,96 ± 1,77
	14	97,97 ± 1,71	97,57 ± 1,96	98,37 ± 1,34
	15	97,07 ± 1,89	96,37 ± 1,96	97,79 ± 1,56*
Technique level index (TLI) (%)	11	10,34 ± 3,95	11,18 ± 4,33	9,51 ± 3,42
	12	12,98 ± 4,41	13,74 ± 5,01	12,21 ± 3,68
	13	15,51 ± 5,72	15,65 ± 4,80	15,37 ± 6,62
	14	20,97 ± 4,47	20,91 ± 4,98	21,03 ± 4,02
	15	23,26 ± 5,41	20,97 ± 4,79	25,56 ± 5,09

The skill to attack a hurdle with both left and right leg was used as a co-ordination efficiency index (CEI). It amounted to percentage difference between time of hurdle race exclusively with dominant attacking leg (in 3-stride rhythm) and time of a hurdle race with both left and right attacking legs (in 4-stride rhythm). CEI informed indirectly about the level of co-ordination abilities of rhythmisation, space orientation and dynamical differentiation of movements. In both groups this index achieved its best value at the age of 14, while the hurdle race results in 3-stride rhythm decreased and the hurdle race

results in 4-stride rhythm attained the highest level. It has to be mentioned that during the whole period of researches higher CEI value displayed group B, which show also systematic regress in hurdle race results (Table 3.). Technique level index (TLI) increased from 10.43 to 23.26% and this trend concerned both groups (Table 3.). From the age of 11 to 13 TLI was better in the group B, and at the age of 14-15 – in the A group. Greatest differences of results in hurdle races in groups A and B were associated with stabilisation of TLI in group A and its significant increase in group B.

Table 4. Characteristics of results of running tests

Test / parameter	Age	Whole (n = 42)	Group A (n = 21)	Group B (n = 21)
		x ± Sd	x ± Sd	x ± Sd
20-40 m run (m/s)	11	5,75 ± 0,41	5,78 ± 0,39	5,73 ± 0,43
	12	5,91 ± 0,43	5,99 ± 0,46	5,83 ± 0,40
	13	6,20 ± 0,46	6,30 ± 0,45	6,10 ± 0,46
	14	6,73 ± 0,65	7,01 ± 0,60	6,44 ± 0,56**
	15	6,80 ± 0,61	7,07 ± 0,64	6,53 ± 0,44**
40-60 m run (m/s)	11	5,94 ± 0,46	5,98 ± 0,49	5,89 ± 0,43
	12	6,13 ± 0,48	6,20 ± 0,49	6,07 ± 0,48
	13	6,34 ± 0,49	6,45 ± 0,53	6,24 ± 0,44
	14	6,73 ± 0,65	7,02 ± 0,65	6,44 ± 0,52
	15	6,94 ± 0,63	7,21 ± 0,59	6,67 ± 0,55
120-180 m run (m/s)	11	5,60 ± 0,45	5,62 ± 0,44	5,57 ± 0,46
	12	5,58 ± 0,52	5,68 ± 0,53	5,48 ± 0,50
	13	5,69 ± 0,46	5,81 ± 0,46	5,58 ± 0,45
	14	5,90 ± 0,48	6,09 ± 0,44	5,70 ± 0,44**
	15	6,17 ± 0,59	6,46 ± 0,47	5,88 ± 0,55**
Velocity endurance index (VEI) (%)	11	94,33 ± 3,35	94,02 ± 2,58	94,63 ± 4,01
	12	91,13 ± 5,53	91,80 ± 6,53	90,46 ± 4,37
	13	89,84 ± 4,29	90,12 ± 3,82	89,57 ± 4,79
	14	87,79 ± 3,27	86,98 ± 3,20	88,60 ± 3,20
	15	89,00 ± 4,49	89,74 ± 3,68	88,27 ± 5,16
Running pace length (cm)	11	127,95 ± 9,09	130,48 ± 9,10	125,43 ± 8,55
	12	135,55 ± 8,27	137,52 ± 7,03	133,57 ± 9,10
	13	146,55 ± 9,00	149,43 ± 7,21	143,67 ± 9,83*
	14	156,91 ± 11,24	161,38 ± 8,34	152,43 ± 12,14**
	15	166,83 ± 10,87	172,10 ± 10,14	161,57 ± 9,00***
Frequency of paces (1/s)	11	4,51 ± 0,34	4,45 ± 0,36	4,57 ± 0,31
	12	4,37 ± 0,32	4,36 ± 0,34	4,37 ± 0,30
	13	4,24 ± 0,32	4,22 ± 0,32	4,26 ± 0,33
	14	4,29 ± 0,29	4,35 ± 0,32	4,23 ± 0,27
	15	4,08 ± 0,33	4,12 ± 0,38	4,05 ± 0,29

Results of trials in all running tests in both groups show every year increase in velocity of particular runs. Only in the 30 m run in the last year of research and in the 150 m run at the age of 12 there was no marked increase relative to previous years observed (Table 4.). Highest velocities were attained in the 40-60 m runs (5.94 – 6.94 m/s). In all years under research, boys from group A achieved better results than boys from group B. Greatest inter-group differences in results of running tests in successive years of research occurred both in start acceleration (20-30 m runs) and in velocity endurance (120-180 m runs) at the age of 13-15.

Adoption of velocity endurance index (VEI) – being a percentage relation of velocity of 120-180 m run to velocity of 40-60 m run – showed decrease in this parameter from 94.33% to 87.79 between the age of 11 and 14.

During the 5-years period of researches significantly changed two fundamental elements of a sprint run – frequency of strides and length of a pace. The latter increased from 127.95 to 166.83 cm. Along with lengthening of a pace decreased – what is obvious – its frequency (from 4.51 to 4.08 paces, Table 4.). This is probably developmental effect, because differences between groups A and B in length of pace were significant at the age of 13, 14, and 15; there were, however, no differences observed in frequency of strides. Lengthening of strides and lowering its frequency, along with increase in sport level, was observed by Herm & Gerrold (1980) and Balsewicz (1995).

In the battery of explosive strength tests of leg muscles (standing triple jump, vertical jump) and shoulder girdle muscles (throws with medicine ball) in successive years occurred significant progress of results, being natural developmental phenomenon (Mynarski 1995, Szopa et al. 1996). Statistically significant differences between groups A and B occurred by the age of 13 in jump and by the age of 14 in throw results (Table 5).

From among flexibility tests, results of forward bend and flexibility index did not show any significant differences between groups A and B. In the test of forward bend, increase in results occurred between the age of 12 and 13, and in next years its level remained unchanged. Osiński (1988), as well as Żak and Sakowicz (1996), examining boys from Poznań and Kraków schools, observed increase in value of this test results only after the age of 13. In all periods of research, results of flexibility tests are better in group B of boys. In the hip joint

flexibility test significant increase in results occurred every year. As concerns flexibility index (FI, relation of length of pace by ladder to length of lower limb) there were no statistically significant differences observed; only at the age of 13 it was higher in the group B (Table 5.).

Table 5. Characteristics of results of flexibility and explosive strength tests

Test / parameter	Age	Whole (n = 42)	Group A (n = 21)	Group B (n = 21)
		x ± Sd	x ± Sd	x ± Sd
Standing triple jump (cm)	11	505,60 ± 49,70	5,18 ± 47,04	493,19 ± 50,27
	12	501,62 ± 47,43	511,43 ± 53,60	491,81 ± 39,20
	13	530,60 ± 50,44	547,10 ± 46,98	514,10 ± 49,35*
	14	571,38 ± 78,04	598,24 ± 74,65	544,52 ± 73,48*
	15	592,95 ± 73,69	624,86 ± 66,88	561,05 ± 67,24**
Counter-movement jump (cm)	11	27,74 ± 5,24	28,67 ± 4,91	26,81 ± 5,50
	12	31,10 ± 4,61	32,05 ± 5,11	30,14 ± 3,94
	13	34,12 ± 5,74	36,57 ± 5,49	31,67 ± 4,98**
	14	36,29 ± 7,06	39,19 ± 6,82	33,38 ± 6,14**
	15	39,00 ± 7,28	41,57 ± 6,98	36,43 ± 6,80*
Throw with medicine ball backwards (cm)	11	414,17 ± 104,60	425,00 ± 106,35	403,33 ± 104,26
	12	517,26 ± 105,87	536,43 ± 114,23	498,10 ± 95,69
	13	618,10 ± 155,04	663,10 ± 158,03	573,10 ± 141,60
	14	764,40 ± 170,85	838,33 ± 168,46	690,48 ± 141,33**
	15	906,43 ± 186,71	978,57 ± 208,70	834,29 ± 130,29**
Throw with medicine ball forwards (cm)	11	475,12 ± 113,60	494,76 ± 120,17	455,48 ± 105,85
	12	548,45 ± 122,69	577,38 ± 123,39	519,52 ± 117,80
	13	678,33 ± 124,91	713,33 ± 116,77	643,33 ± 125,60
	14	769,64 ± 171,35	827,86 ± 180,61	711,43 ± 143,01*
	15	920,12 ± 186,30	1005,71 ± 196,89	834,52 ± 130,38**
Leaning the trunk forward (cm + 20)	11	22,29 ± 6,15	20,48 ± 6,59	24,10 ± 5,21
	12	21,95 ± 5,46	21,00 ± 6,28	22,91 ± 4,46
	13	25,52 ± 6,02	24,95 ± 7,57	26,10 ± 4,05
	14	26,38 ± 6,53	25,95 ± 7,83	26,81 ± 5,06
	15	25,98 ± 5,80	25,95 ± 6,88	26,00 ± 4,65
Stepping onto the ladder (cm)	11	134,62 ± 8,85	135,38 ± 7,27	133,86 ± 10,32
	12	139,57 ± 11,12	141,62 ± 10,02	137,52 ± 12,00
	13	147,86 ± 8,91	147,38 ± 8,15	148,33 ± 9,79
	14	153,33 ± 11,08	153,91 ± 10,43	149,77 ± 10,78**
	15	161,17 ± 11,17	164,71 ± 12,55	157,62 ± 8,46**
Flexibility index (FI)	11	1,81 ± 0,10	1,79 ± 0,09	1,82 ± 0,11
	12	1,79 ± 0,12	1,79 ± 0,11	1,79 ± 0,14
	13	1,83 ± 0,10	1,79 ± 0,08	1,86 ± 0,10*
	14	1,83 ± 0,09	1,84 ± 0,09	1,81 ± 0,10
	15	1,82 ± 0,11	1,83 ± 0,13	1,81 ± 0,10

Determinants of effectiveness of a hurdle-race

Researches being the subject of presented paper proved that hurdle race is a discipline, where from among analysed parameters deciding were velocity preparation and explosive strength of lower limbs.

Observations performed during 5-years period enabled to determine strength and directions of associations between results of a hurdle race, and both somatic and functional variables in successive years of research.

Table 6. Correlation coefficients between hurdle race in 3-pace rhythm and selected tests of motor efficiency and indexes of somatic constitution

Test / parameter	Age (years)					
	11	12	13	14	15	11-15
Mean number of paces (variant 1)	-.66	-.65	-.68	-.70	-.60	-.70
Mean number of paces (variant 2)	-.65	-.29	-.31	-.65	-.69	-.56
Co-ordination efficiency index (CEI)	.14	-.33	-.33	-.14	-.22	.15
Technique level index (TLI)	-.69	-.54	-.52	-.47	-.63	-.40
Starting acceleration	.85	.77	.80	.88	.81	.63
Running velocity	.91	.81	.69	.86	.79	.67
Velocity endurance	.86	.81	.77	.85	.87	.76
Velocity endurance index (VEI)	.50	.19	.19	-.39	.22	.05
Length of a running pace	.40	.33	.41	.57	.59	.27
Frequency of paces	.43	.50	.44	.63	.65	.43
Standing triple jump	.76	.64	.83	.87	.86	.69
Counter-movement jump	.66	.56	.65	.65	.64	.53
Medicine ball throw backwards	.51	.37	.50	.70	.64	.36
Medicine ball throw forwards	.50	.55	.54	.72	.66	.41
Trunk leaning forwards	.29	.14	.21	.31	.16	.22
Stepping onto ladder	.24	.27	.32	.52	.53	.29
Flexibility index (FI)	.25	.26	.14	.26	.27	.24
Body height	.11	.03	.21	.48	.45	.17
Body mass	-.22	-.35	-.18	.14	.06	-.06
Lower limb length	.05	.07	.23	.47	.39	.16
Rohrer index (RI)	-.42	-.53	-.46	-.28	-.27	-.36

$r_{0,05} = .17$, $r_{0,01} = 0.40$

Correlation between both variants of hurdle race was very high (r = 0.94) and remained unchanged in all periods of researches (Table 6.). It testifies to great easiness of choice of attacking leg in those groups of boys, which were not involved in hurdlers training. This is confirmed also by low dependency of co-ordination efficiency index with results of hurdle race in 3-pace rhythm (r =

0.15). Skill in using both left and right leg as attacking one does not contribute to improving the race time. High dependencies of hurdle race results and start acceleration test (in successive years correlation coefficient r varied from 0.77 to 0.88), running velocity (0.69 – 0.91) and velocity endurance (0.77 – 0.87; Table 6) confirm that hurdle race performed by non-trained boys is discipline conditioned chiefly by level of velocity capabilities.

Influence of technique (evaluated indirectly by means of technique level index) on hurdle race results was considerably smaller and lowered up to the age of 14 (r varied from -0.69 to -0.47), and in the last year of research amounted to –0.63.

In the group of boys under research level of explosive strength showed significant influence on hurdle race results. The highest dependency was observed in standing triple jump (r = 0.69) and in counter-movement jump (r = 0.53).

High and still increasing was also dependency of race results on results of medicine ball throws.

Analysis of correlation showed increase in influence of body height and lower limb length on hurdle race effectiveness, along with decrease in influence of body mass (Table 6).

Evaluation of flexibility level, measured by trunk leaning forward, shows its negligible connection with hurdle race result (Table 6.) More relevant flexibility test for hurdlers seems to be stepping onto the ladder; its relationship with hurdle race increases from 0.24 at the age of 11 to 0.53 at the age of 15. It has to be emphasised that this test result depends to great extent on length of lower limb. The flexibility index as a diagnosing parameter by evaluation of hurdle race results occurred asnon-informative. Dependency of FI on velocity of a hurdle race was statistically not significant.

Choice of set of variables best explaining results of a hurdle race

Using the method of selection of explaining variables according to Hellwig (Hellwig 1970, Ryguła and Wyderka 1993) to analyse of gathered numeric data, it was stated that in all age categories set of separate independent variables consisted of at most 6 parameters: 20-40 m run, 40-60 m run, 120-180 m run, index of technique level and standing triple jump (Table 7). These

variables explained in 96-99% the results of a hurdle race in 3-pace rhythm (Table 8). High value of determination coefficient (R^2) proves that choice of tests of motor efficiency, predictive in evaluation of a hurdle race efficiency, was relevant in a group of non-trained pupils under research.

Table 7. Optimum choice of variables explaining velocity of a hurdle race

Age	Regression equation	R	R^2	Hellwig index
11	$y = 0,674 + 0,887x_2 – 0,059x_4$	0,999	0,999	0,981
12	$y = 0,972 + 0,84x_2 – 0,063x_4$	0,978	0,957	0,914
13	$y = 0,069 + 0,186x_1 + 0,001x_5 + 0,225x_3 – 0,019x_4$	0,908	0,825	0,802
14	$y = 0,259 + 0,207x_1 + 0,001x_5 + 0,176x_3 – 0,025x_4$	0,954	0,910	0,956
15	$y = 1,534 + 0,786x_2 – 0,071x_4$	0,998	0,999	0,997

x_1 – 20-40 m run (m/s)
x_2 – 40-60 m run (m/s/)
x_3 – 120-180 m run (m/s)
x_4 – TLI (%)
x_5 – standing triple jump (cm)

In both extreme periods of tests (at the age of 11 and 15) the set of independent variables consisted of only 2 parameters: running velocity and technique level index, and at the age of 13-14 also standing triple jump.

Discussion

Searching for somatic and efficiency parameters crucial to hurdle race has already many years tradition (Doan & Siris 1974, Dołgij 1976, Kostial et al. 1978, Gorbienko & Smirnov 1980). Basing the selection system and training process on the most diagnostic efficiency tests and measurements of somatic constitution ensures better organisation of training and its reliable control, taking into account so called “champion model” (Danisova et al. 1979, Vigars 1989). Results of described research enable, among others, to determine the criteria of selection of boys at the age of 11-15 for hurdle race, by indicating decisive parameters in progress of results in this discipline.

Best progress in somatic and motor parameters under research was observed in the second part of experiment (by subjects at the age of 14-15). Researches of Pierewiercew et al. (1985) showed that in a group of selected

boys, in the period of 5 years of investigation, best progress of results took place in first 10 month of exercises. There is no doubt that these differences were caused by specific training in a selected group, contrary to natural development of diagnosed parameters in a group of boys under research. Fact that despite of great differentiation of somatic constitution and general efficiency, over 90% boys in both groups under research realised 3- and 4-pace rhythm of a hurdle race, testifies to relevancy of a rules choice in successive age categories and to possibility of general adoption of this form of exercises in lessons of physical education.

Changes of body proportions in the period of pubescent leap of body height (age of 14, 15) influenced overcoming the hurdles in easier to perform 3-pace rhythm to greater extent than the more difficult 4-pace rhythm. This phenomenon confirms that in the team of boys, where no specific training is carried out, level of co-ordination capabilities (co-ordination efficiency) does not decide about results in race with one (dominant) attacking leg. This is also confirmed by continuous increase, in successive years of experiment, of technique level index (TLI), which reflects percentage loss of hurdle race velocity compared to run over the same distance without hurdles. Presented results of statistical data suggest unambiguously that not a technique, but velocity preparation is crucial for effectiveness of a hurdle race by non-trained children. Next evidence confirming this connection are high interdependencies of hurdle race results and running velocity tests, starting acceleration, velocity endurance and explosive strength. Influence of a technique (evaluated by means of TLI) on results of hurdle race was considerably lower. Only directing of the training causes that technical preparation plays the greatest role in a final result. Therefore, some papers concerning groups of advanced hurdlers reveal lower significance of running preparation than technical one (Kostial et al. 1978, Iskra 1999).

Decrease by over 6% in level of velocity endurance index (VEI), being the result of lowering of velocities of 40-60 m through 120-180 m runs by boys at the age between 11 and 14, testifies that lactacid anaerobic efficiency increases at this age slower than alactacid one, hence the latter stronger influences results of a hurdle race.

Results of researches unveiled also increase in influence of body height, limbs length, flexibility of hip joint and lowering the body mass for effectiveness of a hurdle races by non-trained boys. On the contrary, investigations of athletes testifies to systematic lowering the influence of somatic constitution parameters along with increase in sport level (Kostial et al. 1978, Iskra 1999). Searching for optimum model of efficiency and somatic constitution of hurdlers concerned high-level competitive athletes (Dołgij 1976, Kostal et al. 1978). In presented paper for this purpose Hellwig method of explaining variables was adopted (Hellwig 1970). Composition of explaining variables shows unambiguously that hurdle race in groups of non-trained pupils is a discipline with anaerobic energetic basis (alactacid maximum anaerobic power), where significant role plays skill in overcoming successive hurdles (20-180 m runs, standing triple jump and TLI). The set of regression equations includes also standing triple jump, being the test with energetic-co-ordination basis and also a valuable test for measuring the degree of advancement of hurdlers. Lack of parameters of somatic constitution in optimum choice of explaining variables shows that this features have no influence on results of hurdle races by non-trained boys at the age of 11-15.

Therefore, results of analysis of multiple regression reveal the possibility of lowering the number of used tests to several most diagnostic, as e.g. sprints and standing triple jump. It is important both in training and selection processes of young hurdlers, as well as by later control of training effects.

Conclusions

1. In the group of non-trained boys, at the age of 11 through 15, it was observed well marked increase in results of chosen efficiency tests. Progress was detected chiefly in the second (between 13 and 15) sub-period of researches and resulted mainly from development processes.
2. Adoption of body height as a basis for changing the principles of a hurdle race influenced the stabilisation of velocity of the run in 5-years period of researches, what confirms rightness of such procedure. Progress of results of hurdle race is associated also with improvement of results in standing triple jump, counter-movement jump and in both throws.

3. Usefulness of mentioned tests in diagnostics of results of a hurdle race in 3-pace rhythm was confirmed by results of correlation analysis. Greatest influence on final result of hurdle races show 120-180 m runs, standing triple jump and 40-60 m runs. It was confirmed also by Hellwig equation of regression. In set of independent variables, determining effectiveness of a hurdle race, there were no parameters of somatic constitution included.
4. Presented facts should be used by recruitment young hurdlers, as well as by control of effects of later training.
5. Results of research confirm possibility of using a hurdle race as an attractive means of shaping of condition and co-ordination capabilities by school children and youth.

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