Selection and Prediction of Speed Abilities in Sprints from Selected Aspects

Scientific monograph

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Abstract

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A high international level of performance in many sports requires a range of measures to enable talented individuals to achieve these goals within a certain timeframe. An essential part of this process is early detection of an individual's talent, predicting his future performance potential and ensuring professional long-term sports training. For the deliberate adaptation of the athlete's body, we need to know the requirements of individual sports and disciplines as accurately and objectively as possible, we need to know the "structure of sports performance". Knowing the structure does not mean only the identification of the relevant factors, but also to reveal the entire network of interrelationships and connections of the influencing factors in relation to the performance criterion and among themselves.

In this work, the author focus to contribute solving the selection activity from the point of view of motor factors, their mutual relations and conditions that are decisive for achieving high sports performance in short-distance running. There are involved two research groups. 19 adult 400 m hurdle males and 95 girls at age 14-17 years. There is available motor, age, somatic and sport performance (initial and subsequent) variables. Mutual relations among variables were studied by correlation coefficients. With the help of multiple correlation and regression there were revealed sport performance structure as well as sport performance prediction equation for longer period.

This research contributes to a deeper explanation of the factors of the structure of sports performance in the 400 m hurdles, especially in terms of strength and flexibility parameters. There are presented prediction equations for the long-term prediction of sports performance in short-distance running The work expands knowledge about the possibilities of long-term prediction in short-distance running.

Key words: sprints, speed, talent selection, sport performance structure, sport performance prediction

List of abbreviations

a	constant of the multiple linear regression equation
ABWkg	active body weight
ABW%	percentage of active body weight
$b_{i.k}$	coefficient of multiple regression
$B_{i.k}$	standard partial regression coefficient (beta coefficient)
$B_{i.k}\ r_{i.k}$	partial regression coefficient of variation BAH – bent arm hang
BH	body height
BW	body weight
CES	centre of elite sports
CSP	central selection procedure
CT	contact time of running step
DA	decimal age
DAFSP	decimal age of final (best) sport performance
DTY	department of talented youth
Ecto	ectomorpfic component
Endo	endomorpfic component
ESP	entry sport performance
Fat%	fat percentage
FBOD	forward bend in obstacle sitting – dominant limb
FBOND	forward bend in obstacle sitting – non-dominant limb

FSP	final (best) sport performance
FT	flying time of running step
F/C	rate of flying and contact times of running step
ITR	index of technique and rhythm (difference between result in 400 m H and 400 m)
LS	length of step
LS/CT	rate of LS and CT
MBT	medicine ball throw
Meso	mesomorpfic component
PU	number of pulls-ups on the bar
r	coefficient of pair correlation
R	multiple correlation coefficient
R^2	multiple determination coefficient
RelBW	relative body weight (rate of BW and BH)
RelLS	relative length of step (rate of LS and BH)
SA	sport age
SASpe	sports age in specialization
SBJ	standing broad jump
SD	standard deviation
SFB	standing forward bend
SLS	spreading legs from sitting
SP_0	sport performance at time (season) of central selection procedure
SP_i	sport performance with i-years (seasons) after central selection procedure

S_R	standard error of prediction
SR	step rate (frequency)
SU2min	sit-ups in 2 min
Tech	running technique
x	arithmetic mean
xPF	average of plantar flexion of both lower limbs
400 m H	400 m hurdling
50mJR	50 m jump run
50mHS	50 m run from a high start
10xSU	10 repetitions sit-ups
30xSU	30 repetitions sit-ups
10 J	ten jumps
12min	12-minutes run
60mLS	60 m run from a low start
20mLS	20 m run from a low start
20mFS	20 m run from a flying start
1.200	first 200 m run in test 2x 200 m
2.200	second 200 m run in test 2x 200 m
ΣRT	sum of the reaction times of the rear and front blocks
Σ200	the sum of the times achieved in 2x 200 m test

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1 Introduction

Contemporary sport and the sports movement is a social phenomenon that brings not only a constant increase in sports performance (especially in its top-level form), but through competitions and sports combat it provides a high level of entertainment to broad sections of the population, encourages youth and adults to active sports activities and to mass-recreational activity (Havlicek et al., 1982a).

The current level of elite sports is characterized by the growth of the number of elite athletes, the high level and great uniformity of their performance. The system of sports training for talented youth is a subsystem of elite sports. On the one hand, it builds on the population and on youth performance sports, on the other hand, it grows into the training of top athletes, because by selecting and training talented youth, it prepares individuals for top sports (Havlicek, 1986).

Top-level performance is increasingly being achieved by very young athletes, whose age was not thought to be suitable and possible for high performance until recently (Fisher, Borms, 1990). If we realize that 5-10 years of sports training is necessary to achieve top sports performance, we must therefore strive for the earliest possible identification of sports talent and the best possible sports training. Therefore, the performance level of a top athlete is often decided already during the sports training of children and youth.

Political interests in the international positive presentation of the state through elite sports laid the foundations for the systematic (centrally controlled) training and talent search for sports. In the former Czechoslovakia, the "Czechoslovak System of High Performance Sport" was created in the 1970s. This new system was designed to identify a number of gifted athletes and provide them with the best possible conditions for training (Sedlacek et al. 1994).

One of the elements of the sports training of talented youth is the staged selection process, which is a necessary condition for the effective functioning of this system. Evaluation of the effectiveness of selection procedures should provide enough objective information about the quality of the selection and thus create a platform for their continuous improvement. From the point of view of sports theory, the central concept is "sports performance". It represents the final goal and at the same time is a criterion for the effectiveness of sports training. Knowing a specific sports performance is an important starting point for determining the appropriate focus and content of sports training during long-term training, as well as for the effective selection of talented youth for a given sport. Sports performance is the result of long-term deliberate adaptation of the athlete's organism to the specific requirements of the given sport, or disciplines. We understand sports performance as a complex, richly structured phenomenon, as a manifestation of the athlete's personality, in which a large number of factors are reflected (Kostial et al., 2018).

For the deliberate adaptation of the athlete's body, we need to know the requirements of individual sports and disciplines as accurately and objectively as possible, we need to know the "structure of sports performance". Knowing the structure does not mean only the identification of the relevant factors, but also to reveal the entire network of interrelationships and connections of the influencing factors in relation to the performance criterion and among themselves. Currently, scientific knowledge of the structure of sports performance is an actual problem of sports theory and practice (Kostial et al., 2018).

Comparing the structure of sports performance determined on samples of athletes of different ages and different sports performance clearly confirmed the change - development (genesis) of the structure (Havlicek, 1986). The importance of individual factors from the point of view of the functioning of the entire structure is different and changes dynamically in connection with age and the growth of sports performance. The constant improvement of the structure of sports performance is a consequence of the long-lasting gradual adaptation of the athlete's organism to training and non-training activities. Within this development process (genesis), not only the importance, but also the arrangement of individual factors of the structure of sports performance changes. These changes are related to the gradual approximation of the structure to the specific requirements of the given performance and the individual characteristics of the athlete's organism (Moravec et al. 2004). From the above, it follows that for effective sports training and the selection of talented individuals for a given sport or discipline, it is important to know the generalized (definitive, ideal) structure of sports performance, i.e. the one to which we strive to get as close as possible during long-term sports training.

From a pragmatic point of view, sports training is focused on improving the individual factors of the structure of sports performance and their alignment into a single unit. The progressive growth of performance presupposes to reveal and improve primarily those factors and the relationships between them that significantly determine sports performance (Dovalil et al., 1982, 2009). Getting to know the structure of the respective sports performance and its development is a prerequisite for the effective selection and training of talented individuals, and thus also ensuring the achievement of high sports performance.

Factor arrangement, hierarchy in space and time (genesis of structure) necessarily follows from the number of acting factors, their specificity and the complexity of mutual relations between them. We refer to those that most affect the functioning of the whole as limiting factors (Kostial, 1984, 2019). The possibility of constructing factor levels follows from the different importance of individual factors. Havlicek (1975) sets aside single factors in the structure of sports performance to have positions of different order.

When examining the structure of sports performance in all its complexity and variability a system-structural approach is applied using the method of dialectical investigation of phenomena. Its basic principle is the investigation of individual systems in mutual dialectical relations and connections, as wholes and not as a sum of parts (Kostial, 1984). From a methodological point of view, Choutka's (1976) important requirement is that within the limits of the structure of sports performance, we must always understand the integrity of sports performance, i.e. mutual interaction of all factors, their dependence, conditioning and compensation. The isolation of individual factors is primarily didactic and research meaning.

The quantification of the relationships of individual factors with each other and as a whole is made possible by appropriate mathematical methods. Thus, we have the possibility to more objectively perceive and analyse the factors of the structure of sports performance, on the basis of which we constantly penetrate deeper into the essence of sports performance.

As we have already mentioned, the structure of every sporting performance is made up of a whole range of factors. In our work, we focus on the most researched area of the structure of sports performance in short-distance running – the area of motor factors. We do this as a result of long-term specialization in this area, as well as for the reasons of the decisive influence of the level of motor factors on sports performance.

1.1 Structure of sports performance in short-distance running

In short-distance runs, or in athletic sprints (smooth and hurdle courses up to 400 m), the goal is to overcome a relatively short running course in the minimum time. Despite the fact that we are talking about simple disciplines of a cyclical nature, research proves the great complexity of sports performance even in this group of athletic disciplines. Factors affecting sports performance and success in sprints can be divided into several areas. These are mostly derived from the focus of the research studies (subject of research) and the complexity of the research. In the theoretical and applied field, we most often talk about motor, somatic, psychological, physiological, social, etc. factors. (Kampmiller, Kostial, 1987).

The most researched area of the structure of sports performance and decisive from the point of view of achieving performance is the area of motor factors. Based on the works of Letzelter (1971); Glesk (1972); Loginov, Alabin, Juskevich (1973); Tabacnik (1979); Ozolin, Voronkin (1979); Kostial, Kampmiller (1984); Dostal (1985); Sedlacek (1986); Kuchen et al. (1987); Kampmiller, Kostial, Sedlacek (1990) and others., we can set aside the following factors of sports performance in short-distance running:

– movement reaction in conditions of low start,
– the ability of running acceleration from a state of relative rest,
– the ability of maximum running speed, or special obstacle speed,
– the ability to maintain the achieved speed as long as possible during the duration of the performance (endurance in speed, or special hurdling endurance).

The mentioned factors are relatively independent, have a rather complex structure and depend on other factors of a lower order.

Havlicek (1975) emphasizes that the level of explanation of sports performance must not be viewed from the absolute isolation of individual levels (e.g. biological, psychological, motor and social), because each level is essentially dependent on, and thus determined by, other levels. We must therefore try to explain the essential and decisive factors. The possibility of constructing factor levels follows from the different importance of individual factors from the point of view of the whole.

Some researchers (Matousek, 1978; Sedlacek, 1979; Matousek, 1980; Rehakova, 1982; Kampmiller, Kostial, 1986; Kostial et al. 2018) dealt with the construction of individual factor levels, focusing mainly on motor and somatic factors. The authors largely agree that there are at least 3 factor levels: In the first, there are mostly complex indicators that are immediate components of sports performance in short-distance running, in the second there are tests of a more analytical nature compared to the movement structure of a running sprint, and they contain less coordination difficulty in terms of the specialty of the movement activity , in the third we mostly find tests of an analytical nature, without coordination demands from the point of view of the movement structure of sprint running (Kampmiller, Kostial, 1986).

It is clear that the lower the factors are, the less immediate impact they have on performance, and at the same time all models prove that the transition from a lower factor level to a higher one is a qualitative transition. Lower-level factors, which are represented by simple, coordination-undemanding tests (we often call them dispositional factors), must be rebuilt through training activities into more complex, coordination-demanding (so-called realizable) factors in order to ultimately manifest themselves in sports performance itself. Here, in addition to direct effects, we also detect indirect effects, mediated through other factors (Kampmiller, Kostial, 1986).

Sports performance in short-distance running is typically multifactorial. It is influenced by a number of factors, which are mutually dependent or independent, affect each other and can compensate each other to a certain extent. All these factors represent abilities and characteristics that must be developed intentionally in the process of long-term sports training (except for the level of conservative, genetically determined factors, the level of which we must already take into account during selection), and which in their complex create sprinting performance. We can measure and register several of them with greater or lesser accuracy. So far, however, we do not know what the exact share of the individual factors of this complex is on sports performance, what are the mutual proportions and links of factors that directly condition the level of a given performance, and how a change in their level will affect a change in sports performance (Kostial, 1984; Kostial et al., 2018).

Tests, respectively battery of tests, are used to determine the level of development of movement skills and technical readiness of short-distance runners. The standards in individual tests, necessary to achieve the expected sports performance, were gradually determined (Dostal et al., 1969. Wright, 1974. Kostial, 1976. Mekota, Blahus, 1983; Moravec et al., 1984; Caha, Moravec et al., 1984; Sedlacek, Cihova, 2009; Peric, Ruzbarsky, 2018; Kostial, 2019; Simonek Jr, Zidek, 2019; Ruzbarsky, Peric, 2021).

The methods of mathematical statistics, which are used to process the obtained empirical data, allow us to objectify our empirical findings. Many authors (Kostial, 1976; Laczo, 1977; Sedlacek, 1979; Matousek, 1980; Rehakova, 1982; Havlicek et al., 1982a; Kostial, 1984; Kampmiller, Kostial, 1986; Laczo, 1987; Sedlacek, 1994) contributed to clarifying the empirical structure of sports performance in running short distances by constructing regression equations to predict sports performance using performance in motor tests, indicators of physical development and possibly some others.

The composition of the above prediction equations supports the already stated statement that the factors of sports performance are of different orders, and that 1-2 motor factors of a complex nature are mainly involved in the explanation of sports performance, in which lower order factors and sports readiness as well are utilized.

1.1.1 Motor abilities (strength abilities, speed abilities, endurance abilities, flexibility, coordination skills)

A person's motor performance is essentially determined by motor abilities, which we characterize as a person's potential movement capabilities. Abilities do not exist in isolation, but are always in a certain relationship with other abilities (Kostial, 1984; Mekota, Cuberek, 2007).

Authors Hirtz (1977); Thies, Schnabel, Bauman (1980); Dobry (1983); Simonek Sr et al. (1985) divide motor skills into:

a) conditioning – they are significantly conditioned by the motor processes of endurance, strength and partly speed abilities.
b) coordination - abilities related primarily to the processes of control of movement regulation - flexibility and partly speed.

Currently, experts also accept the concept of hybrid movement skills, which have a fitness-coordination (mixed) essence (Mekota, 2000; Sedlacek, Cihova, 2009; Ruzbarsky, 2018).

According to Thies, Schnabel, Bauman (1980), coordination skills form a group of motor abilities that are primarily conditioned by coordination. They are therefore closely connected with the processes of regulation and control of motor activity carried out by the central nervous system. They are understood as performance prerequisites, which Hirtz (1977) understands as qualities of the course of control and regulation of movement execution. Mekota (1982), Mekota, Cuberek (2007) and Simonek Jr et al. (2008) state that coordination skills actually determine the degree of utilization of fitness abilities. They can only work in unison with fitness abilities and are applied in whole complexes rather than individually. Bauersfeld, Schröter (1979) and Havlicek (1980) say that coordination skills determine mutual relationships and the involvement of strength, speed, endurance and other abilities in the desired integrated movement unit, and thus they actually coordinate fitness motor abilities.

Strength abilities

Strength abilities have a basic position in the development of human motor abilities. We characterize them as the ability to overcome or maintain external resistance through muscular effort (Dovalil et al., 1982, 2009). Without a sufficient level of strength abilities, it is generally not possible to master sports technique and show the necessary level of active flexibility (Simonek Sr, 1971).

Strength abilities are motor abilities with a heterogeneous structure, the basis of these abilities are maximum muscle strength, dynamic strength and explosive strength (Dovalil et al. 2002; Ruzbarsky, 2018).

Dimitrov (1964), Gralka (1964), Dostal (1965, 1972 and 1985), Havlicek (1968a), Gooden (1979), Kostial (1976, 1984 and 2019). Sedlacek (1983), Joseph (1984), Laczo (1987) and others emphasize the development of explosive and dynamic strength, especially of the extensors of the lower limbs. They argue that a short-distance runner must have an above-average level of rebounding abilities that allows him to quickly reach and maintain maximum running speed, in a hurdler, to perform a long bounce on an obstacle and maintain a running rhythm in rhythmic units. Gralka (1964) and Gorbenko, Smirnov (1980) point out that this is rebound explosiveness not only in a one-time but also in a repeated manifestation (endurance in the explosive and dynamic power of the lower limbs). The effective implementation of movement activity also requires adequate strength of other muscle groups: abdominal and back muscles, rear thigh muscles as well as the girdle muscles of the upper limbs and arms.

With the lengthening of the race distance in short-distance runs (200 and 400 m), the importance of endurance in strength events increases. In hurdle races, the static strength of the calf muscles and back mats has an irreplaceable place in the amortization of the foot after the run over hurdles (Sedlacek, 1979).

Heyward, Ellios, Romer (1968), Kovar (1974 and 1981) and Alabin, Juskevich (1977) state that strength abilities are considered to be less genetically determined, because their level can be significantly influenced by training during ontogenesis, especially in connection with growth muscle mass, by improving neuromuscular coordination and chemical processes during muscle work. According to Sykora (1972), Pavek (1977), Simonek Sr (1983), Moravec (1990) and Laczo et al. (2014), the most intensive natural development of strength abilities takes place at the ages of 7-8, 13-14 and 16-18 years. For the deliberate and intensive development of strength abilities, the appropriate age is from 18-20 years old (Platonov, 1980, Janouch, 1983).

In short-distance running, we mainly test the explosive strength of the lower limbs - test standing broad jump, dynamic strength - the triple jump, quintuple jump or tenfold jump, jumps alternately or one leg at a time, speed and strength abilities - the 50 m jump run test, strength endurance is then determined in practice most often by the maximum number of barbell curls (or endurance on barbell curl) on the jumping bar and the maximum number of repetitions in the sit-ups test in 1-2 minutes (Sedlacek, 1991; Sedlacek, Cihova, 2009).

Speed abilities

By the term speed, we mean the ability of a person to carry out a movement activity under the given conditions in the minimum time. The activity is short and does not cause fatigue (Zaciorskij, 1970). Speed during movements is the result of the constant action of the earth's gravity, muscle activity and other personal characteristics and abilities of the individual.

Movement-conditioned reflexes require maximum mobility of the processes of irritation and attenuation when performing the movement at high speed, which allows maximum rapid alternation of contractions and relaxation of muscle groups (Sedlacek, 1979).

Many authors (Filin, 1974; Matvejev, 1977; Dostal, 1985; Kampmiller, Kostial, 1986 and others) agree that speed is a heterogeneous ability, and that the term speed abilities is more correct. Based on the researches of Zimkin (1956), Farfel (1960), Kuchen (1965), Harre et al. (1973), Dudarev, Plachtijenko (1975), Vajcechovsky (1975) and Matvejev (1977) identified 3 basic (elementary) forms of speed:

- movement reaction speed (we measure it by latent reaction time),
- the speed of one-time movement (we measure it by the quantities of speed and acceleration when performing one-time movements without external resistance),
- speed of tempo (frequency) of movements (we measure it by the number of movements per unit of time).

Elementary forms of speed are mutually independent. This applies especially to reaction time indicators, which in most cases do not correlate with movement speed indicators. The synthesis of the three mentioned forms determines all manifestations of speed. Ter–Ovanesjan (1978) and Kuchen et al. (1987) emphasize that speed is one of the least generalized abilities. They found that not only the seemingly different forms of their expression, but also similar external manifestations (acceleration and maximum running speed) do not correlate with each other.

The level of speed abilities that a person can achieve depends not only on the degree of development of his speed abilities and characteristics, but also on a number of other factors - the level of explosive and dynamic strength, mobility, flexibility of technique mastery, etc. According to Dostal (1975), sprinting speed can be increased by developing the following factors: stride length, acceleration speed, frequency and efficiency of leg movement per second, form and technique of sprinting, and fitness level. Therefore, training is closely connected with the development of other physical abilities and with the improvement of technique. This is consistent with Alabin (1974), Matvejev (1977) and Tabacnik (1979), who state that with the deepening of sports specialization, the ways of developing speed skills increasingly merge with the ways of improving specific movement habits and skills.

Of the factors of sports performance in sprints mentioned so far, the factor of maximum running speed (special hurdle speed) has the most significant position, which is the limiting factor of performance in all short-distance runs. As the distance increases, the importance of the factor of movement reaction to the starting shot as well as the factor of acceleration speed decreases, on the other hand, the importance of the factor of speed endurance (or special hurdle endurance) increases.

Of the individual factors of running speed, reaction time provides the least possibilities for improving performance (Letzelter, 1977). Factors of acceleration speed and speed endurance are relatively easier to train during sports training. This is due to the fact that they are closely related to strength and endurance abilities, which are less genetically determined in the aforementioned connection. The most difficult to develop and genetically highly determined is the maximum speed factor. It is a key factor for selection and training in short distance running (Baughman, Takahe, 1984). Dostal (1975) reports that typical sprint programs to date speed up recovery between sprints, delay deceleration, and allow speed to be maintained over a longer stretch, but the maximum speed the sprinter is able to use remains untouched. A rational sprinting program, aimed at developing maximum speed capabilities, requires a transition to anaerobic training (share of 75%) and the use of programs aimed at increasing the frequency of steps and their length.

From the works of Sykora (1972); Filin (1974); Alabin, Juskevic (1977); Filin, Fomin (1980), Moravec (1990), Laczo et al. (2014) and others, it follows that the optimal age for the development of speed skills is 7-17 years. However, it is necessary to mention that there is a lack of accurate and reliable measurements on younger files. We believe that it is most likely possible to extend the mentioned interval to younger age categories as well.

In athletic practice, acceleration speed and maximum speed tests are most often used. Acceleration speed is measured by the time achieved on sections from 10 to 30-50 m from a low or semi-high start. When determining the distance, we base it on the fact that more advanced and specialized athletes can accelerate for a longer time, due to special training as well as a high maximum speed. We test the maximum speed by the time achieved on sections 10-30 m long with a approach of 20, 30 and more meters; it is about the runner having his maximum speed already at the first finish line; it follows from the above that the faster (from the point of view of maximum running speed) the tested individual is, the longer approach must be. When determining the distance, we base it on the fact that a more powerful sprinter reaches his maximum speed later and maintains it over a longer distance (Sedlacek, 1991). When testing maximum and acceleration speed, we recommend using fully automatic time measurement with an accuracy of 0.01 s (photocells).

In athletics, the speed of one-time movement (the so-called action speed) and frequency speed are also of considerable importance. The speed of one-time movement is mostly tested in laboratory conditions (tapping hands and feet). In practice, we measure running frequency by dividing the number of steps by the time achieved on a certain section.

Measurement of simple and complex movement reaction is used only rarely in practice, due to its considerable genetic determination and the small possibility of progressive influence by sports training. The time that elapses from the moment of the shot to leaving the blocks is most often used as a criterion of reaction speed.

Speed endurance testing will be covered in the section where we mention endurance testing.

Endurance abilities

Endurance is the motor ability to perform a long-lasting motor activity at a certain level without reducing the efficiency of this activity (Dovali et al., 1982 and 2012; Kasa, 2000; Moravec et al. 2004).

The decisive criterion of endurance is the duration of the activity, its intensity and effectiveness.

Dovalil (1986) divides endurance abilities as follows:

- endurance at the speed at which ATP-CP energy systems are activated (activity lasts up to 15-20 s),
- short-term endurance during which the lactate energy systems are activated (activity lasts up to 2-3 min),
- medium-term endurance, during which lactate and aerobic energy systems are activated (activity lasts up to 8-10 min),
- long-term endurance during which aerobic energy systems are activated (lasts more than 10 min).

We consider the average level of general (balanced, aerobic or long-lasting) endurance to be the basis and prerequisite for developing other types of endurance, which we refer to as special. As the distance shortens, the proportion of anaerobic energy coverage increases.

Many authors (Bulancik, 1955; Havlicek, 1968b; Dostal, 1972; Tolstopjatov, 1975; Sedlacek, 1986; Kostial 2019, etc.) consider special endurance, even in short-distance running, to be a decisive ability, into which all prerequisites and qualities should be transformed during long-term sports training of a sprinter. The importance of special endurance in short-distance running increases with the increasing length of the disciplines. We most often use the terms speed endurance and special (hurdle) endurance for these disciplines.

Research confirms that speed endurance is an ability that can be significantly developed in the process of sports training and thereby create the prerequisites for a significant increase in performance. A prerequisite for the prospective effectiveness of deliberate action is the prior exhaustion of natural speed reserves and respect for the functional readiness of the organism. The development of special hurdle endurance is even more challenging, because it is connected not only with the level of endurance in speed, but also with the improvement of movement activity and especially the rhythm of hurdle running (Sprague, Mann, 1982; Kostial, 1984; Sedlacek, 1988; Kostial, 2019).

Developing endurance abilities is possible already at a younger school age. This is evidenced by the measurements of Guzalovskij (1977), Alabin (1981) and Moravec (1990), which speak of the most progressive increase in endurance abilities at the age of 7-9 years. This dynamic of growth in the level of endurance abilities decreases with increasing age. Stagnation occurs in girls after the age of 13, in boys it is much later (Moravec, 1990). Most authors agree that the deliberate development of special endurance should be shifted to the age period of 16-19 years, in order to avoid premature adaptation to the used intensive training means.

In athletic practice, performance in a 12-minute run is used to determine balance endurance in short-distance running. In order to determine special endurance, performance is evaluated on sections with a length of 80 to 150% of the race distance, where the intensity of the activity is as close as possible to, or even exceeds, the race distance. 120, 150, 200, 300 and 500 m running tests are most often used in athletic sprints, or combinations of the mentioned distances (e.g. 2 x 200 m with a rest interval of 2 min, etc.). As a rule, special hurdle endurance is not evaluated by special tests. For 400 m smooth runners, the difference in times on the second and first half of the race track is sufficiently informative (Sadovskij, 1970; Cerneva, 1971; Artjushenko, 1976; Brejzer, Ivkin, 1981; Dostal, 1985).

Flexibility

Flexibility (mobility) is an ability related to the range of human movements. It includes a whole range of partial phenomena, such as flexibility (elasticity) of muscles, but also the ability of muscle relaxation (Choutka, 1973). Flexibility depends above all on the range of joint mobility (which is limited by the anatomical structure of the joint), on the flexibility of ligaments, tendons and antagonist muscles, their release and stretching, and at the same time on the strength of the relevant acting muscles - agonists (Choutka, 1973; Simonek, 1980; Dovalil, et al., 1982).

Mobility is a specific ability that enables the performance of a certain sport skill in optimal quantitative and qualitative dimensions (Choutka, 1973). Each sport places special demands on the manifestation of mobility. In most sports, the maximum level of anatomical flexibility is not required, but only its optimal level. Therefore, flexibility is not a limiting factor of sports performance, but only an optimal determinant. On the contrary, its excessive level (hypermobility) can become an obstacle in achieving high sports performance.

The above general statements also apply in their entirety to short-distance running. Movement activity in short-distance running takes place approximately up to the level of the middle zone of maximum range (including hurdle runs). An optimal level of mobility is a prerequisite for acquiring a rational technique (Ozolin, 1970; Puzio, 1974; Wright, 1974; Sedlacek, 1979; Dovalil et al., 1982 and 2012; Razumovskij, 1983; Peric, 2010 and others). The importance of the level of mobility increases in short-distance runs with increasing height of hurdles, delaying states of stiffness mainly in the second part of the run and not disrupting the running technique, possibly the inter-hurdles rhythm and the technique of the hurdle run (Sedlacek, 1979; Kostial, 1984; Matousek, Sedlacek, 1988; Bred, Rahmani, Dufour, Messonnier, Lacour, 2002). No less important is the fact that maintaining an adequate range of motion also has an antihypertensive effect, compensates for unilateral training load, has a regenerative effect on the movement-supporting apparatus, enhances parasympathetic processes in the athlete's organism, and thus also acts as a prevention against possible injuries (Mall, 1982; Anderson, 1983; Jirka, 1984; Stulrajter, 1984; Javurek, 1986; Vojtasak, 1989).

The development of flexibility is significantly genetically determined (Sermejev, 1970; Kovar, 1974 and 1981). Most people are born with relatively significant prerequisites for performing physical activity on a large scale. As a rule, flexibility decreases with increasing age. The sensitive period for its development is the age of 10-14 years (Sykora, 1972; Alabin, Juskevic, 1977; Filin, Fomin, 1980; Simonek Sr, 1980).

In short-distance running, the most commonly used flexibility test is to determine the depth of the forward bend from the stand. We thus evaluate the flexibility of the spine and the length of the muscles that mainly cover the back of the athlete's body. Among the other tests, the forward bend test in the obstacle seat has found its application in practice, especially for hurdlers (Sedlacek, 1991).

Coordination abilities (skills)

Coordination abilities (skills) are complex, relatively independent prerequisites for the performance regulation of movement activities, which are formed and developed in movement activities based on dominantly inherited but influential morphological functional mechanisms that can be improved through training (Simonek Sr, 1990; Simonek Jr et al. 2008).

Among basic coordination skills can be included: orientation, kinesthetic-differentiation, balance, reaction and rhythm skills (Hirtz, 1985; Simonek Sr, 1985). These basic coordination abilities were supplemented by Schnabel, Harre, Borde (1994) with two additional abilities: the ability to combine movements and the ability to reconstruct motor activity.

Each athletic discipline places its own specific demands on coordination skills. An athlete should achieve a sufficient level of all coordination skills and a high level of those that play a decisive role in the given athletic discipline (Simonek Sr, 1990).

In short-distance running, a highly above-average to borderline level of rhythmic, kinaesthetic-differentiation and reaction ability is a necessary condition for achieving top-level performance. A high level of coordination skills is manifested in sprints by an effective running technique on smooth and hurdle courses, which enables the achievement of maximal performance from the point of view of individual (especially speed) movement abilities.

A high level of coordination skills favourably affects the most specific component of sports training – technical preparation (Choutka, 1976; Dovalil et al. 2012). It is about the optimal application of movement abilities and psychological qualities with a focus on acquiring and stabilizing sports movement and at the same time improving the degree of variability of sports skills in the conditions of specialized sports performance. Djackov (1972) talks about technical mastery, by which he understands the perfection of movement components, the rationality of technical structures and the degree of their control.

The optimal age for the development of coordination skills is when the relevant centres in the central nervous system are still malleable. The most favourable period is from 6 to 12 years. From the age of 14, when the development of the vestibular apparatus ends, the natural growth in the development of coordination skills ends (Simonek Sr, 1990; Moravec, Sedlacek, 1991).

Coordination skills, or at least some of them, fundamentally contribute to high sports performance. The problem from the point of view of testing these abilities lies in the fact that it is usually a very specific movement. In practice, it is shown that the level of coordination skills is manifested in adequately mastered movement activity, and that the most reliable indicator is the quality of sports performance (Sedlacek, 1991).

As a rule, we test coordination abilities in the initial stages of the selection, most often with various obstacle courses or shuttle runs, which more or less comprehensively tell about the level of coordination skills (Aahper, 1965; Havlicek, 1973; Brar, 1985; Hirtz et al., 1985; Chauhan,1989; Moravec, 1990; Hirtz, 2007).

In the 100 m, 110 m and 400 m hurdles, a suitable indicator of the level of coordination skills (the so-called "Technique and Rhythm Index") is the difference between the time on the obstacle course and the performance on smooth run on the 100m respectively 400m.

1.1.2 Biological factors

The biological side of being trained is conditioned by a whole complex of morphological, physiological and biochemical factors. In addition to body structure as a morphological basis and assuming full health, psychological factors, neuromuscular functions and energy processes limit sports performance in individual sports and disciplines to varying degrees (Komadel, 1976).

In individual athletic disciplines, physical development has a different position in the structure of sports performance. Knowing the somatic factors of sports performance is important in the search for gifted individuals for sports and in view of their strong genetic determination (Susanne, 1971, 1977; Defrise, Susanne, 1978; Simkova, Ramacsay, 1983; Simkova, 1987; Simonek Jr, Zídek, 2019 and others) to a certain extent, they limit the success of athletes in the given discipline (Matousek, 1988). In short-distance runs, length, volume and somatotype characteristics are most often determined (Kampmiller, Kostial, 1986). Length features serve us to assess the biomechanical prerequisites for success in the discipline. We most often measure the values of body height, length of the lower limbs, length of the foreleg, length of the thigh, length of the foot, possibly also their mutual ratios; e.g. Kostial (1976 and 2019) determines the index of height proportions, Saffa (1977) determines the ratio of the length of the foreleg and thigh, etc. Length features have different importance in short distance running according to the disciplines. While in the 100 m sprint there are relatively large possibilities for compensating these factors, as the length of the sprint increases and in the hurdle races, mainly individuals who have the necessary length parameters at an optimal level prevail. This is proven by a number of studies carried out at prominent international events, but also on groups of less efficient and younger athletes (Tanner, 1964; Eiben, 1972; Vacula et al., 1975; Saffa, 1977; Matousek 1977; Sodhi, Sidhu, 1984; Kampmiller, Kostial, Sedlacek, 1988; Selingerova, Kampmiller, Kostial, 1988). We consider the optimal body height values for short-distance running to be 180-190 cm for men and 165-175 cm for women.

Of the volume characteristics, we most often evaluate body weight, relative body weight, active body weight and body fat in sprints. According to current knowledge, the optimal body weight for achieving peak performance in short-distance running is 72-80 kg for men and 56-63 kg for women. From the point of view of active body weight, sprinters belong to the group of athletes with very well developed muscles. In terms of the amount of subcutaneous body fat, they belong to the groups with the smallest values (Havlicek, 1982b). Volume characteristics do not show statistically significant dependences with sports performance in adult elite athletes (Havlicek, 1982b; Joseph, 1984; Kampmiller, Kostial, 1986).

Many authors studied the somatotypes of elite athletes (Tanner, 1964; Gedda, 1966; Stepnicka, 1968 and 1972; Selingerova, Kampmiller, Kostial, 1988). In short-distance runners, the mesomorphic component prevails, and a certain inclination towards ectomorphism is manifested in long sprints and especially in hurdlers (Dostal, 1985).

It turns out that a higher degree of the mesomorphic component (5-7) is a decisive prerequisite for achieving high sports performance in most sports, including short-distance running. On the contrary, in this group of disciplines, a high value of the endomorphic component is a suppressor of achieving high sports performance.

Physical features are about 70% genetically conditioned, and therefore we can only influence the somatotype to a small extent. Strokina (1965) claims that dedication to athletics affects only unstable morphological features (body weight, muscle mass, subcutaneous fat layer, etc.) and other peculiarities of body structure must be connected with the selection of beginners.

Jakovlev (1974) and Zimkin (1975) consider the physiological and biochemical point of view to be one of the decisive factors in the adaptation of the organism in the training process.

Short-distance runs are categorized as physical exercises performed at maximal and submaximal intensity. They are characterized by a relatively short duration (10-60 s) and an effort to achieve the maximum speed of movement activity.

During performance in short-distance runs, it is not possible to provide enough oxygen, therefore an oxygen debt arises as a result of anaerobic metabolism. The increase in energy metabolism (Seliger, Pribylová, 1972 state 250-350 times) has an effect on the high consumption of energy found directly in the muscles. According to Seliger (1967) and Jakovlev (1974) in short-distance running, energy is released from more than 90% anaerobically. Some research shows that the representation of aerobic metabolism is significantly higher during short-term activity of submaximal intensity. Serresse et al. (1988) and Van Praagh et al. (1991) indicate a 13-28% share of aerobic metabolism for 30 s of submaximal intensity exercise.

The oxygen debt reaches more than 29 l O_2, the internal environment of the muscles changes, where insufficiently oxidized metabolic products accumulate and disorders of neuro-dynamic processes occur. At the end of the track, typical muscle stiffness and concentrated feelings of fatigue occur. Overall, the performance is limited by the functional capacity of the circulatory and respiratory systems, the effect of acid-base balance disturbance on the central nervous system and the ability to release energy in anaerobic conditions (Sedlacek, 1979). The ability of the organism to release energy - without sufficient supply of oxygen - is considered a decisive ability in short-distance running, which must be taken into account already during the selection (Seliger, Trefny, 1967; Seliger, Pribylova, 1972; Komadel, 1976).

Limit values of anaerobic energy release in the organism were determined after 400 m smooth and hurdle runs. The lactate level reaches up to 25mmol.l^{-1} (Novak, 1982 and 1983; Matousek, 1986).

Reliable and valid results about the level of anaerobic capacity of the organism can be determined by performance in maximal runs at distances of 500 + 300 m with 15-minutes rest interval or 2x 200 m with 2-min. rest interval. Similar results can already be found in laboratory conditions when evaluating endurance in running at submaximal to maximal intensity.

The possibility of performing anaerobic work is given by the percentage ratio of aerobic (slow, red) and anaerobic (fast, white) muscle fibres of the body. Up to 90% representation of fast fibres was found in short-distance runners. It is also important to note that the proportion of fibres does not change significantly during ontogenesis, even due to different loads (Karlson, 1975; Counsilman 1976; Kostial, 1984; Sedlacek, 1987). Today, a methodology has been developed that allows determining the ratio of white and red muscle fibres, or anaerobic and aerobic possibilities of the athlete's organism by means of testing in laboratory conditions, thus replacing the unpleasant method of muscle biopsy (Tkac, 1989; Hamar, Tkac, 1990).

1.1.3 Psychological factors

In short-distance running, the psychological component has a special position in the structure of sports performance. It represents the highest level of regulation of the organism's activity, and in this sense it is superior to the performance capacity of the given individual (Macak, 1982).

Psychological factors are manifested in a certain way of action and behaviour of an athlete. Of the factors to euphoria sports training and the achievement of high sports performances in athletic sprints, the most frequently mentioned are: psychological stability, desire to excel, appropriate degree of aggressiveness, properly focused emotionality, motivation, tenacity, ability of kinetics perception, psychological tolerance for internal changes, etc. (Tosnar et al., 1962; Dostal, 1972; Kostial, 1976; Sedlacek, 1979; Havlicek, 1982b; Dostal, 1985; Prakash, 1986 et al.) On the contrary, extroversion, neuroticism, timidity, inability to concentrate are most often cited as deprivation factors (Havlicek, 1982b).

From the above, it follows that for athletic performance in short-distance running, it is probably optimal for an individual to have as many factors as possible to euphoria the achievement of high athletic performance, and to eliminate his deprivation dispositions to a minimum during the preparation process.

1.1.4 Social factors

The past, post-war historical period of the struggle between two antagonistic social systems, when politics was artificially introduced into sports, also had its impact on the social factors of sports performance. Many countries systematically worked to convince the surrounding world of their economic, social, social and political prosperity through the high sports performance of their representatives.

The mentioned approaches led to the artificial influence, especially of social conditions, which affect the discovery and development of sports talent. Havlicek (1982a, 1982b) includes 3 types of areas:

– macro-social conditions that manifest in social consciousness (value of sport, place and status of sport in society, its support),
– mid-social conditions, which are manifested in the distribution of material, organizational and personnel prerequisites for playing sports to specific regions and institutions,
– micro-social conditions (social-psychological factors), which are manifested as the influence of the immediate social environment on the individual, his motivation, perseverance and willingness to devote time and effort to preparation, to increase the level of sports performance.

For the most significant interventions in social conditions that reliably enhance the final product - sports performance, often at the cost of possible value, character and personality deformations of the athlete and his surroundings, e.g. belong to:

– insignificant glorification and politicization of sport at the state level,
– creating pressure on the management apparatus in sports from the point of view of achieving sports achievements,
– doping,

- the creation of institutions (sports classes, sports schools, elite sports centres) narrowly focused only on the effect of sports training - sports performance (Sutcliffe, 1988; Riordan, 1986; Sedlacek et al., 1994).

The aforementioned possible interventions in the social conditions of the athlete often introduce contradictions and even confusion into the intended unified or concurrently directed educational action of the family, school, sports team, coach, officials, etc. We often see the results of the mentioned condition as sports oversaturation, sports failures, psychological instability, inability to integrate into normal life, etc. (Orlick, 1980; Fisher, Borms, 1990; Broom, 1991). The analyses of Bloom (1985) and Hemery (1986) on groups of elite athletes prove that a favourable social climate is best implemented through family activities, where demands are placed on future athletes in the entire socio-cultural breadth and where favourable, but not violent, and artificial, conditions for sports.

1.2 Prediction of sports performance

Sports practice confirms that high sports championship can be achieved only by an extremely talented individual, under favourable conditions and with optimal preparation. Talent selection is closely related to the questions of sports performance prediction. The task of selection is to provide sports practice with a selection methodology and more comprehensive scientific knowledge about sports prerequisites, which would help to eliminate intuitiveness in coaching work, and with the help of which suitable individuals would be more objectively selected for the individual articles of sports training (Moravec, Selingerova, 1987). For these reasons, we are also helped by the construction of profiles of top athletes, from which we then derive selection requirements, on the basis of which later sports performance is predicted (Fisher, Borms, 1990).

Talent selection is a process in which, based on the level and pace of growth of somatic, functional, motor, psychological and social characteristics, we try to assess the suitability of an individual for a certain sport (Harsanyi, Martin, 1983). A special problem of prediction is to find indicators suitable for prediction - predictors that are relevant from the point of view of the definitive level of sports performance, are manifested at the time of assessment of talent, can be measured, and which are the most developmentally stable (Baur, 1988). Performances in tests that evaluate the level of genetically determined and developmentally stable properties and abilities, which are considered decisive in the factor structure of a given sports performance, are considered more suitable for prediction (Siris, 1974; Havlicek, 1974; Bulgakova, Voroncov, 1978; Gajdarska, Siris, 1976; Siris, Gajdarska, Racev, 1983; Kostial et al. 2018; Kostial 2019).

The long-term prediction of performance is uncertain, burdened with a significant risk of errors caused by the influence of variables that do not manifest themselves at the time of the prediction, or due to their variability, cannot be evaluated (Wendland, 1984; Fisher, Borms, 1990; Simonek, Zidek, 2019). With the shortening of the prediction time, the predictive validity should increase (Siris, 1974; Havlicek, 1974; Gajdarska, Siris, 1976; Havlicek et al., 1987).

When predicting sports performance, we still cannot clearly answer whether it is more appropriate to predict on the basis of the level or changes in the level of performance in tests over a certain period (Gajdarska, Siris, 1976; Havlicek et al., 1987; Havlicek, 1990). The assumption that in the selection process one must consider not only the level, but also the pace of development, especially those abilities on which success in the chosen sport depends, was expressed in works of a theoretical nature, e.g. Guzalovskij (1977); Bulgakova, Voroncov, Cherkasov (1980); Aule, Loko (1983). Currently, it seems that the experimental researches of those authors, which confirm the higher predictive validity of the level of movement abilities, than the changes that occurred in this level over a certain period of time, have found a greater response in sports practice (Havlicek, 1974; Bulgakova, 1978; Ruzickova, 1986; 1987; Peric, 2010; Rankinen, Bouchard, 2011; Babic, Blazevic, Katovic, 2012; O'Sullivan, 2013; Baker, Wattie, Schorer, 2018).

1.3 Current problems of selecting talented youth in short-distance running

The target categories of sports training for talented youth consist of elements aimed at versatile and harmonious personality development and elements that create the basis for the prospective achievement of top-level performance, especially the development of knowledge, properties, abilities, skills and technical-tactical mastery, which form the basis of the development of talent. A necessary condition for the functioning of this system is also regular selection procedures, aimed at selecting youth according to the level of talent and orienting them to sports in which they have the prerequisites to achieve top-level sports performance (Havlicek, 1986).

The process of long-term sports training from beginners to international success takes 5-10 years. Making a sufficiently probable and reliable prediction for such a long time is very difficult. Therefore, specialists approach stage modelling, i.e. they form ongoing models of the athlete's complex readiness. From the works of Havlicek (1973, 1982 a, b, 1986), Kodym (1978), Kuchen et al. (1981), Dreke (1982), Popov, Suslov, Livado (1984), Bulgakova et al. (1984), Simonek Jr, Zidek, (2019) and others, there are three to six stages in the selection of athletically talented youth.

From the point of view of the selection of athletically talented youth for short-distance running, the stages of specialized selections are of decisive importance: specialized selection I and II at the age of 12-13, respectively 15-17 years (Havlicek, 1982a, 1986; Siris, Gajdarska, Racev, 1983; Laczo, 1983; Kostial, Kampmiller, 1984) during which candidates are selected according to the pace of performance growth in control exercises and according to the athletes' dispositions. Specialized selection II has the task of selecting individuals with specific dispositions for a certain discipline. They are athletes who have achieved a certain required sports performance and have such a set of dispositions that provide a guarantee of prospective performance growth.

In current sports practice, we mean selection as a system of organizational and methodical measures of a complex nature, on the basis of which we determine the prerequisites of athletes for a specific specialization (Kostial, Kampmiller, 1984). According to Siris, Gajdarska, Racev, (1983), Kostial, Kampmiller (1984), Popov, Suslov, Livado (1984), Moravec, Selingerova (1987), Grasgruber, Cacek (2008), Horvath et al. (2010), Simonek Jr, Zídek (2019), the selection criteria should consist of an assessment of:

- morphological-functional indicators (anthropometric features, determination of biological age etc.),
- levels of development of motor abilities, including coordination skills,
- dispositions for motor skills (docility) and the level of psychological qualities,
- the state of the decisive functional systems of the body,
- genetic and social factors.

The issue of selection for sprinting disciplines is all the more complex, as practice shows narrow limits for improving speed abilities, only a minimal improvement of initial performance through narrowly specialized training (Kampmiller, 1984). According to Filin (1974), Tabacnik (1979), Siris, Gajdarska, Racev (1983), it is only 1.0-1.5 s in the 100 m run. Therefore, high requirements must be placed on the selection.

An important role in the assessment of prediction in the selection of sprinters is also played by the assessment of sports age in specializations. All-round running readiness is important for young people, which expands functional possibilities, develops all movement skills and, above all, allows in the next stages of preparation to significantly increase the volume of running at submaximal and maximal intensity, which prospectively ensures the achievement of high sports performance (Kostial, Kampmiller, 1985; Kostial et al., 1990). An important prerequisite for a high initial performance is not age (Tabacnik, 1979; Siris, Gajdarska, Racev, 1983; Popov, Suslov, Livado, 1984; Moravec, Selingerová, 1987; etc.), but previous general, versatile training.

Predisposition is also an integral part of the factors that determine the selection of youth for sports (Havlicek, 1982a; Fisher, Borms, 1990). The observation of twins (Grebe, 1956; Klissouras, 1973; Kovar, 1974, etc.), studies of sportsmen's pedigrees (Moser, 1960, 1966, 1966, 1974; De Garay et al., 1974; Rehor, 1975, etc.) contributed to revealing the genetic conditioning of sports prerequisites and monitoring the relations between parents and children, or between siblings. In 2003, the human genome mapping project was completed. This fact opened up unprecedented possibilities also in the identification of sports talent (Simonek, Zidek, 2019). Ahmetov and Fedovskaja (2015) state that up to 66% of sports performance depends on genetics. The rest relates to sports training, nutrition, sports equipment and facilities, athlete motivation, sleep levels and other factors. Genetic testing therefore proves to be an alternative method by which parents of children and coaches can find out which sport a given individual has the prerequisites for (Roth, 2012). Changing conditions in the course of life, constant improvement of sports training as well as discoveries in genetics reveal unprecedented adaptation possibilities, which also changes statements about the degree of genetic predisposition.

Sports practice confirms to us that the importance of innate dispositions for sprinting sports performance is considerable (Robinson et al., 1974; Kovar, 1974; Zaciorskij, 1974; Billouin, 1985; Lee, 1987; Fisher, Borms, 1990; Ahmetov, Fedovskaja, 2015 etc.). From the point of view of selection, inherited, more conditional abilities have the greatest prognostic significance - dispositional assumptions, while assumptions of a more complex nature applied in movement activity - realisation assumptions, are of lesser importance (Kostial, Kampmiller, 1984; Sedlacek, 1989; Havlicek, 1990).

The results of a one-time testing (evaluation) of movement performance say more about the level of real readiness for achieving sports performance than about the prospective possibilities of athletes (Tabacnik, 1979; Suvalov, Borzov, Ljulko, 1980). At the age of 13-17 years, it is not possible to ensure a reliable prediction only by determining the initial state of development of motor abilities, but especially by the ratio between this level and the growth rates for the first 1-2 years of training (Siris, 1974). Based on this knowledge, the authors compile norms for athletically talented youth in short-distance running in control tests for individual age periods (Tabacnik, 1979; Siris, Gajdarska, Racev, 1983; Kostial, Kampmiller, 1985, etc.).

In the past, experts tried to look for speed, frequency and spatial characteristics in the kinematic structure of running movement. With the ever deeper investigation of the structure of sports performance in sprints as well as the improvement of technical possibilities in the analysis of sprint running, many authors have recently been dealing with the time characteristics of the duration of the contact and flight phases of the running stride (Kunz, Kaufmann, 1981; Kampmiller, 1984; Bosco, Vittori, 1986; Hlina, Adamcikova, 1989; Stepanek, Moravec, 1990; Mero, Komi, 1990; Kampmiller et al., 1991; Holček et al., 1991; Mero, Komi, Gregor, 1992). Some of these characteristics show a considerable conservatism in the longitudinal and intersexual development of individuals (Kampmiller, 1984; Moravec, Selingerova, 1987; Kampmiller, Kostial, Sedlacek, 1990; Vanderka, Kampmiller, 2013; Martin-Fuentes, Tillaar, 2022), and therefore their further investigation provides extremely up-to-date information to make more effective the selection of talented athletes youth in short-distance running.

It follows from the works of Bogdanov (1974) and Bacvarov (1976) that they consider the duration of the contact time phase favourable for sprinters when running at a maximum speed of 0.090 s and less. Tabacnik (1979) states that only 10 out of a thousand individuals possess an excellent support time (90-105m.s) in 12-15-year-old youth. Spokas, Filin, Janskauskas (1977) experimentally proved that in 13-14 and 15-16-year-old children, the level of speed skills improves significantly in those who had a shorter contact time when entering the experiment. Tjupa et al. (1978) and Smirnov, Ivanov, Fedjajev (1978) report that as the running speed increases, the duration of the running step - both the contact and flight phases – decreases (Kampmiller,1983, 1984). Bosco, Vittori, Matteucci (1985), Billouin (1985), Dysko, Kravcev (1987), Kampmiller, Kostial, Sedlacek (1988) and Hlina, Adamcikova (1989) also found a dependence between the duration of the contact time phase and running speed. From this they conclude that it is an important criterion for determining speed abilities, because it determines in a certain sense its effectiveness and reflects the level of abilities to concentrate neuromuscular effort. The most important seems to be the effort to shorten the passive part of the contact phase - amortization.

Smirnov, Ivanov, Fedjajev (1978), Kampmiller, Kostial (1986), Levcenko et al. (1987), Kampmiller et al. (1991) and others examine the relationship between flight time and running stride contact time of elite sprinters. They agree that this ratio must be greater than 1.0. Kuznetsov at al. (1979) talks about the model characteristic of 1.3. Levchenko (1987) found Johnson's ratio of 1.47 at the Goodwill Games (Moscow, 1986) with a performance of 9.96 s in the 100 m run! It seems that the higher the ratio coefficient of the flight and contact phase a sprinter achieves, the better his sports performance is.

The frequency of steps also has a close relation to the acceleration and maximum running speed (Cornett, Lyle, 1977; Kampmiller, 1983; Kostial, Kampmiller, 1984, 1985; Orosz, 1989). According to Jolly, Crowder (1987) and Levcenko et al. (1987), high-performance sprinters differ from low-performance sprinters more in step frequency than in stride length. Well-trained sprinters reach their top speed later than less-trained sprinters and maintain it over a longer distance. The decrease in speed at the end of the track is mainly caused by a decrease in the frequency of steps. Bosco, Vittori (1986), Kampmiller et al. (1991) and Holcek et al. (1991) experimentally proved that the frequency (rate) and length of steps increase at maximal running speed. When running for 100 m, the best sprinters achieve a stride rate (frequency) in the section of maximum running speed (from 5.2 to 5.5 steps per second). Falbriard, Mohr, Aminian (2020) proved that contact time significantly increases, while speed and step frequency significantly decrease with time during 400 m hurdle races.

Kampmiller (1984), Kampmiller, Kostial, Sedlacek (1990) and Vanderka, Kampmiller (2013) based on the analysis of indicators of body height and weight, maximum running speed, stride length, duration of the flight and contact time phase of the running stride and their ratio, stride rate (frequency) of the Bratislava youth aged 7-19 show considerable developmental conservatism in the duration of the flight and contact time phase of the running step, the ratio of flight time and contact time as well as the rate (frequency) of steps. Also study of Korhonen, Mero, Suominen (2003) confirm conservatism of these factors until age 65 years both among men and women. From this, they conclude on the suitability of determining these factors in the selection of athletically talented youth in short-distance running, as reliable predictors of possible future top-level sports performance.

Despite the ever-increasing knowledge, the selection of talented youth for short-distance running remains an unsolved problem. We have listed some current problems in this area, which give an opportunity to objectify the selection process. In our work, we will primarily focus on solving the selection activity from the point of view of motor factors, their mutual relations and conditions that are decisive for achieving high sports performance in short-distance running, some somatic indicators and monitoring the subsequent sports performance achieved.

2 Objective, hypotheses and tasks of the work

For the purposes of our work, we have two researches available. One set consists of performance and top-level adult male competitors (19 individuals) 400 m hurdlers, where we have available their sports performances in sprint disciplines and testing of strength parameters and flexibility (sports performances and tests were done during one season). The second set is made up of girls (95 girls) aged 14-17, where we have available their complex testing (41 variables) and sports performance in sprint disciplines at the time of testing and in the following years (up to 4 years) after testing.

2.1 Objective

The goal of the research is to contribute to the explanation of the factors of the talented youth selection in short-distance running through a quantified estimation of the empirical structure of sports performance and numerical expression of the dependence of changes in sports performance on motor, somatic and other variables.

2.2 Hypotheses

On the basis of theoretical and empirical research knowledge, own experience, interviews with competitors and coaches, and logical considerations, we assume that the level of talent and comprehensive provision of sports training play a significant role in performance growth in short-distance running. Based on the formulation of the research objective, we establish the following specific hypotheses:

H1:

In order to achieve high performances in the 400 m hurdles, one must have a certain adequate level of strength readiness and flexibility:

a) Regarding indicators of strength readiness, we believe that the explosive and dynamic-endurance strength of the lower limbs plays a significant role in shaping performance in the 400 m hurdles; the most significant indicator of strength readiness will be the 50 m jump run test.
b) Furthermore, we assume that the sports performance in the 400 m hurdles can be explained to a decisive extent by strength readiness tests.
c) We assume the dependence of sports performance on the level of flexibility.

d) We believe that, in addition to the 400 m smooth performance and the index of technique and rhythm, tests of strength abilities and flexibility will participate in explaining the structure of sports performance in the 400 m hurdles.

H2:

a) We assume that the level of athletic performance in short-distance running will be largely determined by special realizative and dispositional motor tests in our group of girls.

b) We expect less dependence on indicators of strength abilities, technical readiness and physical development.

c) Of the age variables, the decimal age will show the highest significance; we assume also a slightly lower significance of the other two age indicators - the length of the sports age and the length of the sports age in specializations.

d) We assume high self-prediction validity for indicators of subsequent sports performance.

H3:

Based on the knowledge of the starting situation of the athletes and the monitoring of subsequent sports performance, we will be able to predict expected changes in sports performance. The revealed degree of dependencies will allow us to construct regression equations with a forecast of sports performance for a longer period of time, with a pedagogically acceptable number of variables and accuracy.

2.3 Tasks

1. To analyse the interrelationships of tests of strength abilities, flexibility and sports performance in men's 400 m hurdles. On this basis, explain the hierarchy of relationships between dependent and independent variables in the structure of sports performance.
2. To determine the interrelationships between the variables of motor readiness, physical development and age, current and subsequent sports performance in a group of girls. Based on the analysis of interrelationships, reveal the predictive potential of individual variables and select the most suitable variables into reduced sets of predictive equations with the greatest possible probability of revealing subsequent sports performance.

3 Material and methods

3.1 Groups characteristics

The first studied group consisted of 19 male 400 m hurdlers. The performance of all of them was higher than the limit of the first performance class, of which four met the standard of the master class. All of them are specialists in the 400 m hurdles and in 1978 they placed to 38th place in the Czechoslovak standings. The age of the hurdlers ranges from 18 to 29 years, the average age is 22.9 years. All of them have been involved in athletics for at least four years. The number of trainings per week varies from 4 to 7. Most of the competitors were university students. Some were also members of the Centres of Elite Sports (CES). Five of them were, or are, senior representatives of Czechoslovakia.

The second group consists of 95 girls who participated in the central selection procedure (CSP) in the years 1981-1986. Follow-up of subsequent sports performance was watched until 1989. This selection procedure was organized by the former Czechoslovak athletics union and was attended by invited athletes - female sprinters who achieved significant successes in athletic sprints within Czechoslovakia in previous seasons. The average age of our group was 16.7 years; the youngest was 13.8 years old at the time of testing and the oldest was 22.1 years old. The average sports age was 6.4 years and the average sports age in the specialization was 2.2 years. Most of the girls were high school students.

3.2 Determination of the research situation

The methodological basis for evaluating the selection of talented youth in short-distance running is deeper knowledge, innovation, objectification and rationalization of the selection process.

By examining the issue of the selection process in short-distance running, we will try to answer the question of how the resulting effect of the system develops in the next period of time. We will aim to determine the predictive validity of the test battery, contribute to the explanation of the structure of sports performance and assess some external influences showing affinity to sports performance in short distance running.

We chose ex-post facto research as the research method. To solve the tasks of empirical research, we set the conditions under which the research will take place in terms of the selection of probands and their conditions, observation time and acting stimuli (Havlicek, 1983).

We solve the first task based on the situation:

(G_{1-19}; S_{1-p}; SP_0)

Legend: G_{1-19}: group of 19 adult men in 400 m hurdles,

S_{1-p}: *athlete´s training status,*

SP_0: sport performance in the year of states assessment.

In this defined situation of research conditions, we can (Havlicek, 1983):

a) Determine the level of conditions (training) of athletes, or sports performance.
b) Determine the connections between states 1, 2, ...p. It makes it possible to delimit the factor structure of the studied area of conditions, to recognize duplications in the assessment of conditions and to determine the optimal reduction of the test set.
c) Find out the connections between conditions and sports performance. It allows to describe the structure of sports performance, as the variability of individual states (independent variables), explains the fluctuation of sports performance (dependent variable).

We solve the second task based on the situation:

(G_{1-95}; S_{1-p}; SP_0) t_0 - (SP_1) t_1 - ... - (SP_4) t_4

Legend: G_{1-95}: group of 95 girls tested in sprints events (100 m – 400 m H),

S_{1-p}: *athlete´s training status,*

SP_0: sport performance in the year of states assessment.

SP_{1-4}: *sport performance one - four years after states assessment.*

In this defined situation of research conditions, we can (Havlicek, 1983):

a) Determine the level of conditions (training) of athletes, or sports performance.
b) Find out the connections between states 1, 2, ..., p. It makes it possible to delimit the factor structure of the studied area of conditions, to recognize duplications in the assessment of conditions and to determine the optimal reduction of the test set.
c) Find out the connections between conditions and sports performance. It allows to describe the structure of sports performance, as the variability of individual states (independent variables), explains the fluctuation of sports performance (dependent variable).
d) Find out the connections, or relationships between the states of athletes 1, 2, ..., p at time t_0 and sports performance at time t_1, ..., t_4.

3.3 Methods of finding empirical data

For the first task to find out the necessary data, we compiled a questionnaire that consisted of tests to find out the level of flexibility, strength readiness and sports performance. Of the 45 questionnaires sent out, 21 were returned properly filled in - that's 46.5%. We eliminated two competitors from the group, whose performance was lower than the limit of the 1st performance class. The subjects filled out the questionnaire with the help of their trainers in September 1978, i.e. during the period when they regularly trained and competed. We verified the method by measuring the monitored indicators in 26.3% of the test subjects.

We used the following tests:

1. Strength testing:
   - ten jumps (10J), the distance reached is measured with an accuracy of 0.01 m,
   - standing broad jump (SBJ), the distance reached is measured with an accuracy of 0.01 m,
   - 50 m jump run (50mJR), the time and number of jumps are measured and the index is calculated as the ratio of the number of performed jumps to the time achieved,
   - 10 sit-ups from lying down for time (10xSU), the time to perform ten repetitions is measured with an accuracy of 0.1 s,
   - 30 sit-ups from lying down for time (30xSU), the time to perform thirty repetitions is measured with an accuracy of 0.1 s,
   - push-ups (PU), the number of complete push-ups is measured with an accuracy of 1 complete repetition.

With these tests, we determined the explosive, dynamic and dynamic-endurance strength of the lower limbs. For the upper limbs, we used a standard test - the maximum number of push-ups. We tested the abdominal and back muscles in sit ups lying down exercises performed at maximum speed, the aim was to determine the level of dynamic and dynamic-endurance strength of the abdominal and back muscles.

2. Flexibility testing:
   - depth of forward bending (SFB), the overlap (+) or failure to reach (-) the plane of the pad is measured with an accuracy of 0.01 m,
   - leg spread in the frontal plane (SLS), the distance between the centre of the heels is measured with an accuracy of 0.01 m,

– forward bends in obstacle sitting on both sides (FBOD, FBOND), the overlap of the alternate upper limb is measured with an accuracy of 0.01 m.

With the mentioned tests, we determined the flexibility of the spine, the mobility in the thigh joints and the flexibility of the thigh muscle groups (mainly the inner and back part of the muscles).

3. We determined sports performance from a questionnaire and from official Czechoslovak tables; these were the best performances of the 1978 season in runs at:
   – 100 m,
   – 200 m,
   – 400 m,
   – 400 m hurdles, achieved in races under regular conditions.
   – We calculated the technical-rhythmic index as a time difference: 400 m H – 400 m = ITR. The basic statistical characteristics of this set are presented in Table 1.

Table 1 Basic statistical characteristics of male group (n = 19)

Tests (units)	x	SD	max	min
SFB (cm)	17.3	5.0	33	10
SLS (cm)	138.2	12.2	159	117
FBOD (cm)	18.4	7.7	38	6
FBOND (cm)	16.0	7.6	34	6
10J (m)	29.5	2.2	33.5	26.0
SBJ (cm)	271.6	16.2	305	228
50mJR (1)	2.75	0.3	2.33	3.20
10xSU (s)	10.8	0.9	9.7	13.0
30xSU (s)	35.9	4.6	31.5	45.8
PU (1)	12.1	4.0	26	7
100 m (s)	11.15	0.2	10.9	11.5
200 m (s)	22.73	0.5	21.9	23.8
400 m (s)	50.22	1.36	46.9	52.0
400 m H (s)	53.69	1.36	50.6	55.9
ITR (s)	3.48	0.87	1.6	4.8

In the second task, we worked with the following variables:

1. Performance criteria: Performances in all disciplines in short-distance running in group of girls were converted to point values according to tables specially developed for the purpose of mutual comparison of individual athletic disciplines (Spiriev, Kovács, 1987). We differentiated four types of performance criteria:
   - entrance performance, that is the best performance that was achieved before CSP,
   - concurrent sports performance (SP_0) the best performance that was achieved during the season when the CSP took place,
   - the subsequent sports performances (SP1...4), these are the best performances that were achieved in the following seasons after the CSP with an interval of 1, 2, 3 and 4 years,
   - "definitive sports performance" (FSP) is the best sports performance achieved during the follow-up period.
2. Age variables:
   - decimal age (DA) with an accuracy of 0.1 years,
   - sports age (SA) with an accuracy of 1 year - the number of years in which the athlete systematically engaged in controlled physical activity,
   - sports age in specializations (SASpe) with an accuracy of 1 year - the number of years in which the athlete focused on a specific discipline.
3. Somatic and somatic typological variables:
   - body height (BH) with an accuracy of 0.001 m,
   - body weight (BW) with an accuracy of 0.5 kg,
   - relative body weight (RelBW) ratio of body weight in grams and body height in centimetres,
   - active body weight (ABW) in kg and percentage of active body weight (ABW%),
   - body fat percentage (FAT%),
   - endomorphic (Endo), mesomorphic (Meso) and ectomorphic (Ecto) components of the somatotype (accuracy to 0.1).
4. General physical performance. For this purpose, we used the most commonly used standardized tests in our country:

- running for 50 m jumps run from a high start (50mHS); the index is evaluated: the ratio of the number of jumps with an accuracy of 0.1 m to the time achieved with an accuracy 0.1 s,
- standing broad jump (SBJ) with an accuracy of 0.01 m,
- depth of forward bend (SFB) with an accuracy of 0.01 m,
- medicine ball throw (MBT) weight 2 kg, with an accuracy of 0.1 m,
- endurance in push-up (EPU) on the jumping bar with an accuracy to 1 s,
- sit-ups in 2 min (SU2min) with accuracy of 1 repetition,
- 12-minute run (12min) with accuracy of 5 m.

5. Variables of technical readiness:
   - evaluation of the sprint technique (TECH) on a scale of 0-5 points by an expert group consisting of three coaches (accuracy to 0.5 points).
6. Special motor performance – implementation variables:
   - 60m from a low start (60mLS) performed according to the rules of athletics with an accuracy of 0.01 s,
   - 20 m from a low start (20mLS), was measured as the first 20 m in the 60 m run test from a low start with an accuracy of 0.01 s,
   - 20 m from a flying start (20mFS), was measured as the last 20 m in a run of 60 m from a low start with an accuracy of 0.01 s,
   - 50 m jump run (50mJR), the time and number of jumps are measured and the index is calculated,
   - 2x 200 m with a rest interval of 2 min. The times achieved on the first section (1.200), on the second section (2.200) and in the sum of the times on both sections (Σ200) are evaluated.
7. Special motor performance – dispositional variables: We obtained data for these variables with the help of the "locomometer'' device developed at Research Institution of Physical Culture in cooperation with the Department of Theory a Didactics of Athletics of the Faculty of Physical Education and Sports, Comenius University in Bratislava, while running at maximum speed on a section of 20 m in flight. We directly measured or calculated the following variables:
   - step rate (frequency - SR) with an accuracy 0.01 Hz,

– running step contact time (CT) with an accuracy 0.001 s,
– running step flight time (FT) with an accuracy 0.001 s,
– index flight time divided by running step contact time (FT/CT) with an accuracy of 0.01,
– average step length (LS) with an accuracy of 0.01 m,
– relative step length (RelLS) with an accuracy of 0.01 – is defined as the ratio of step length and body height,
– step length index divided by contact time (LS/CT) with an accuracy of 0.01.

8. Force variables:
   – the average size of the plantar flexion of the right and left lower limbs (xPF) with an accuracy of 1 N.

We performed all measurements and tests in relatively identical conditions in Nymburk, where there is a special training facility for ensuring year-round sports training of sprinters (sprinter's tunnel with a tartan track). Relatively equal conditions for achieving sports performances were ensured by taking into account only those performances that were achieved under regular conditions according to the rules of athletics. The basic statistical characteristics of this set are presented in Table 2.

Table 2 Basic statistical characteristics of girls group (n = 95)

Tests (units)	x	SD	max	min
BH (cm)	168.48	5.54	180.5	158.6
BW (kg)	55.18	4.81	66.0	45.0
RelBW ($g.cm^{-1}$)	329.88	24.57	394.0	277.0
Fat% (%)	12.87	2.27	20.8	9.2
ABW (kg)	48.56	3.95	57.1	40.3
ABW% (%)	87.12	2.24	90.8	79.2
Endo (1)	2.50	0.55	4.0	1.5
Meso (1)	3.66	0.98	6.6	1.0
Ecto (1)	3.73	0.93	6.0	1.4
DA (year)	16.66	1.39	22.1	13.8
SA (year)	6.35	2.29	12.0	2.0
SASpe (year)	2.16	1.01	5.0	0

ESP (points)	892.00	70.43	1038	680
50mHS (s)	6.98	0.31	7.8	6.2
SBJ (cm)	231.83	10.90	260.0	212.0
SFB (cm)	13.91	4.99	33.0	3.0
SU (1)	81.62	15.78	128.0	45.0
EPU (s)	38.86	18.80	120.0	9.0
MBT (m)	8.40	1.63	13.0	4.8
12min (m)	2741.0	204.0	3110	2000
ΣRT (ms)	759.71	72.20	926.0	503.0
60mLS (s)	8.49	0.25	9.26	7.96
20mLS (s)	3.62	0.11	3.89	3.40
20mFS (s)	2.43	0.10	2.64	2.19
Tech (points)	3.02	0.64	4.5	1.5
SR (Hz)	4.32	0.24	5.0	3.9
CT (ms)	119.37	13.87	167.0	94.0
FT (ms)	110.37	10.88	138.0	86.0
F/C (1)	0.93	0.14	1.3	0.6
LS (cm)	193.03	9.76	221.0	169.0
RelLS (1)	1.15	0.06	1.34	1.0
LS/CT (1)	1.65	0.15	2.1	1.3
50mJR (1)	14.31	1.13	17.1	11.7
xPF (N)	1156.05	223.80	1730.0	680.0
1.200 (s)	27.28	1.06	29.9	24.5
2.200 (s)	29.05	1.35	34.0	26.4
Σ200 (s)	56.34	2.08	63.9	51.9
SP_0 (points)	892.0	77.90	1063	700
FSP (points)	938.52	77.17	1119	708
DAFSP (year)	18.17	1.72	22.9	14.6
TFCSP (year)	1.51	1.58	7	0

A more detailed description of the tests we used can be found in the publications of the following authors: Havlicek, 1968b, 1982a; Stepnicka, 1972; Pavek, 1977; Slamka, 1981; Mekota, Blahus, 1983; Kostial, 1984; Kampmiller, 1984; Moravec et al. 1984; Blaha, 1986; Moravec, 1990; Neumann, 2003; Sedlacek, Cihova, 2009 and others.

3.4 Data processing and evaluating the obtained data

Sports performance, indicators of physical development and motor performance as individual variables are characterized by basic statistical characteristics - arithmetic mean (x), standard deviation (SD), minimum (min) and maximum value (max). In the mathematical-statistical analysis, we relied on non-parametric methods in the set of men due to its low number. On the contrary, for the set of girls, of which there were up to 95 in the set, we assumed a normal data distribution, and therefore we used parametric methods to process the results.

In pair correlation analysis, we express the relations between variables by pair correlation coefficients according to Spearman and Pearson (Reisenauer, 1970). These served us as a starting point in both tasks for multiple correlation and regression analysis, which we characterized by the coefficient of multiple correlation and determination. We performed the prediction of sports performance through multiple linear regression equations with the standard error of prediction. We assessed the significance of the monitored dependencies at the 1% or 5% level of significance according to table values of r (Winner, 1962 Bakytova et al. 1979 Guilford, 1964).

We determined the predictive validity coefficients using pairwise correlation analysis.

In the pedagogical interpretation of the established facts, we relied on basic logical methods.

4 Results and discussion

4.1 The share of the level of strength readiness and flexibility on sports performance (on the structure of sports performance) in the 400 m hurdling

The dependence of sports performance on the six monitored indicators of strength readiness is shown in the correlation matrix (tab 3). By order correlation analysis, we found a statistically significant dependence, at the 1% level, between the performance of the 400 m smooth to the ten jumps (r = - 0.59) and the 50 m jump run (r = 0.67); the 5% significant dependence was found between 40 m smooth and thirty repetitions of sit-ups (r = 0.55), as well as between the performance of 200 m with the ten jumps (r = - 0.47) and with the 50 m jump run (r = 0.51). The other indicators do not show a statistically significant dependence on any of the performance criteria.

Table 3 Correlative coefficients between watched parameters in male group of 400 m H

Tests	SLS	FBOD	FBOND	10J	SBJ	50mJR	10xSU
SFB	.05	.78++	.83++	.38	.23	-.31	.14
SLS		.39	.21	.35	.06	-.36	-.36
FBOD			.89++	.56+	.37	-.51+	.02
FBOND				.47+	.45	-.45	.12
10J					.47+	-.86++	-.49+
SBJ						-.43	-.16
50mJR							.63++

Tests	30xSU	PU	100 m	200 m	400 m	400 m H	ITR
SFB	-.14	.08	-.37	-.52+	-.27	-.15	.19
SLS	-.55+	.33	-.19	-.23	-.17	-.17	.03
FBOD	-.40	.12	-.45	-.57+	-.36	-.27	.15
FBOND	-.21	.08	-.31	-.45	-.22	-.20	.05
10J	-.75++	.07	-.33	-.47+	-.59++	-.34	.38
SBJ	-.20	.04	-.44	-.39	-.15	.06	.34
50mJR	.83++	-.30	.34	.51+	.67++	.52+	-.22
10xSU	.75++	-.15	.09	.20	.37	.21	-.22

Tests	PU	100 m	200 m	400 m	400 m H	ITR
30xSU	-.22	.31	.41	.55+	.33	-.33
PU		-.04	-.07	.03	.04	.03
100 m			.87++	.59++	.47+	-.19
200 m				.67++	.52+	-.23
400 m					.79++	-.31
400 m H						.34

Legend: + - p > 0,05 (45.5)

++ - p > 0,01 (57,5)

Using multiple correlation and regression, we found that all indicators of strength readiness are correlated with sports performance in the 400 m hurdles (R = 0.772). By expressing the multiple coefficient of determination, we found the dependence of sports performance in the 400 m hurdles to 59.7%. The biggest benefit (according to partial regression coefficients of variation) is the performance of the 50 m jump run (up to 91.3%), which seems to absorb a large part of the other strength tests (tab 4).

Table 4 Multiple correlation and regression of strength tests to sport performance of 400 m H

Tests	$\mathbf{B_{i.k}}$	$\mathbf{B_{i.k}\, r_{i.k}}$	$\mathbf{b_{i.k}}$	**a**
10J	-.337	-.195	.360	17.249
SBJ	.064	.027	.036	
50mJR	.516	.913	7.786	
10xSU	.214	-.O43	-.293	
30xSU	.332	-.125	-.111	
PU	.043	.017	.017	
		R^2= .596		
		R = .772		

By reducing some tests of strength readiness, we found that the greatest contribution to clarifying the performance in the 400 m hurdles is the set – standing broad jump, 50 m jump run and thirty repetitions of sit-ups, where the coefficient of multiple correlation is R = 0.676. By expressing the multiple coefficient of determination, we found the dependence of sports performance to 45.7% (tab 5).

Table 5 Multiple correlation and regression of reduced strength tests to sport performance of 400 m H

Tests	$B_{i.k}$	$B_{i.k}\,r_{i.k}$	$b_{i.k}$	a
SBJ	.064	.029	.039	34.675
50mJR	.516	.614	5.237	
30xSU	.332	.188	-.167	
		R^2= .457		
		R = .676		

It turned out, in agreement with hypothesis 1a, that the most appropriate indicator of strength readiness tests is the 50 m jump run for the minimum number of jumps and the best possible time. This test primarily represents the dynamic endurance strength of the lower limbs. Statistically significant, at the 1% level, it correlates with the ten jump (r = - 0.86) and with the ten, resp. thirty repetitions of sit-ups (r = 0.63, r = 0.83). The relationship between the 50 m jump run and the standing broad jump is just below the critical table value (r = -0.43). The number of pull-ups did not show any relation to the performance criteria.

We explain the high dependence of strength readiness in the test of 30 repetitions of sit-ups on the performance criteria (tab 3) by involving the relevant muscle groups during the technically correct overrun of hurdles. Particularly important is the strength readiness of the hip-trunk muscles, manifested in pulling the thigh of the swing leg to the chest during the rebound and leaning on the hurdle.

In the 50 m jump run test, not only the dynamic-endurance strength of the lower limbs and pelvic plexus is demonstrated, but also the speed aspect of the performance, which we take into account (the time to perform 50 m sprints) is also important. Mainly for this reason, we believe that this test of strength readiness shows a greater dependence on our sports performance criteria than the ten jumps test (tab 3).

By order correlation analysis, we found that leaning forward (r = 0.52) and reaching the arm in the hurdle seat (r = 0.57) correlates with the performance at 200 m, at the 5% level. All other relationships between flexibility and performance mostly fell far below the critical table values (tab 3).

When using multiple correlation and regression, we also did not find significant dependence. The complex of four flexibility test items correlates with the best sports performance in the 400 m hurdling (R = 0.306). According to the multiple determinant, the dependence can be explained to 9.4%. According to the partial determinants, the greatest contribution to the explanation of sports performance is the forward bend in the obstacle seat (14.1%).

Considering the higher body height of most hurdlers (Matousek, 1978 - his arithmetic mean was 181.3 cm) and the lower height of the obstacles (91.4 cm), we can assess the flexibility of our group as adequate. It is not a limiting factor at the given performance level of our group. It allows you to perform movements in a relaxed, coordinated manner and with sufficient amplitude, so it does not prevent high-quality performance of the technique.

We made several selections of tests of flexibility and strength readiness and, using multiple correlation and regression, investigated the relationship with sports performance in the 400m hurdles, 400m and the index of technique and rhythm.

In the 400 m hurdles run, multiple correlation and regression showed the highest value and choice - forward bend in the hurdle sit (on the dominant swing leg), 50 m jump run and thirty repetition of sit-ups (R = 0.546). According to the coefficient of determination, this choice explains sports performance to 29.8%, which is statistically insignificant.

Multiple correlation and regression of the selected sets with regard to the technical-rhythmic coefficient reached very low values. We believe that it is because the technical-rhythmic index includes the entire complex of manifestations of movement and intellectual abilities. Therefore, we assume that we cannot significantly contribute to the explanation of the index of technique and rhythm with the help of a complex of indicators of flexibility and strength readiness.

For the 400 m run, we tried three reduced sets of flexibility and strength readiness tests. In the selection, which consisted of a forward bend, 50 m jump run and thirty repetitions of sit-ups, a dependence was found at the 1% level (R = 0.673). According to the coefficient of determination, we can explain the sports performance in the 400 m smooth at 45.3%, from the calculation of the partial regression coefficients of variation it follows that the 50 m jump run test has the largest share in explaining the performance - up to 45.3% (tab 6).

Table 6 Multiple correlation and regression of strength and flexibility tests to sport performance of 400 m

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
SFB	-.266	.016	-.016	42.612
50mJR	.670	.436	2.881	
30xSU	.550	-.001	-.0006	
		R^2= .453		
		R = .673		

We believe that the results found in multiple correlation and regression correspond fairly accurately to the real situation. They show less dependence of sports performance in hurdle run on the complex of indicators of flexibility and strength readiness. They also confirm that the structure of 400 m hurdles performance includes many more and more diverse factors than the structure of 400 m smooth performance.

Matousek (1978) states that up to 98% of the performance in the 400 m hurdles can be explained by the performance in the 400 m smooth with an index of technique and rhythm. At the same time, 400 m smooth explains the performance from up to 75% and the index of technique and rhythm from the remaining 23%.

In our work, we created several reduced triplets of indicators, in which the independent variables were represented by the performance in the 400 m smooth run, the technical-rhythmic index, and the third independent variable was one of tests of flexibility or strength readiness. The dependent variable was performance in the 400 m hurdles. The multiple correlation and regression coefficients were very high. The highest was when placing the flexibility test - extending the arm in an obstacle sitting position. According to the coefficient of determination, we managed to explain the performance to 99.9% (tab 7).

Table 7 Multiple correlation and regression of FBOD, 400 m and ITR to sport performance of 400 m H

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
FBOD	-.297	.005	-.003	1.115
400 m	.789	.773	.998	
ITR	.335	.221	1.002	
		R^2= .999		
		R = .999		

In the correlation matrix, we can find the dependence of sports performance in the 400 m hurdles run with the 400 m smooth run at the 1% level (r = 0.79). The performance in the 400 m run mostly depends on the performance in the 200 m run (r = 0.67 – 1%), which we used in our work. From the flexibility tests – the forward bend and forward bend in the hurdle seat have an effect on the 200m performance as we have already mentioned.

The technical-rhythmic index is certainly important in shaping the performance in the 400m hurdles. However, we did not manage to significantly contribute to the clarification of the structure of this index through the indicators of flexibility and strength readiness.

Schematically, according to the obtained results, the construction of the performance structure is shown in the most important features on the figure 1.

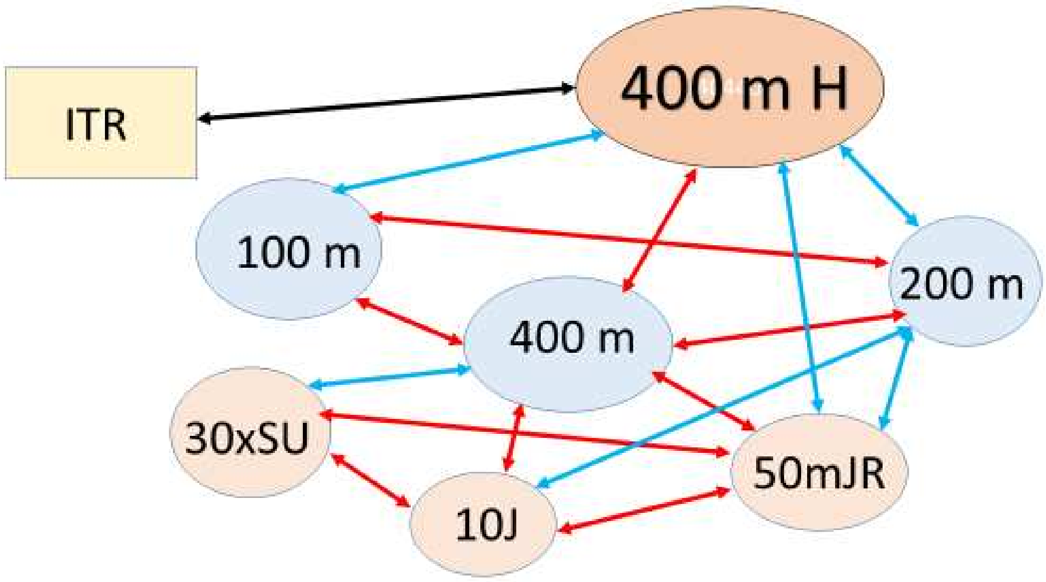

Figure 1 Construction of the sport performance structure in the most important features in men group of 400 m hurdling

Legend: p>0.01

p>0.05

expected dependence

4.2 The share of dependent variables on the selection and prediction of sports performance in short-distance running in group of girls

In the indicators used, we find several groups of tests according to their focus. They are the following groups of variables: somatic, age, general motor performance, special motor performance (realization and disposition) and variables of subsequent sports performance achieved after CSP up to 4 years.

Individual somatic factors often show a high correlation relationship among themselves, which mostly clearly exceeds the 1% level of significance (tab 8).

Table 8 Correlation coefficients between somatic and some selected variables in group of girls

Tests	BH	BW	RelBW	Fat%	ABWkg	ABW%	Endo	Meso	Ecto
BH		.526+	.197	-.160	.560+	.170	-.294+	-.381+	.557+
BW			.980+	.356+	.892+	-.349+	.244	.297+	-.387+
RelBW				.468+	.793+	-.465+	.394+	.517+	-.681+
Fat%					.017	-.998+	.951+	.411+	-.510+
ABWkg						-.015	-.070	.146	-.247
ABW%							-.953+	-.414+	-.515+
Endo								.414+	-.553+
Meso									-.724+
Ecto									
DA	.198	.390+	.373+	-.030	.400+	.029	-.061	.018	-.141
50mHS	.057	-.084	-.144	.586+	-.123	-.062	.046	-.002	.191
SBJ	.041	.165	.196	.638+	.228	-.052	.038	.237	-.155
MBT	.197	.360+	.338+	-.075	.351+	.075	-.118	-.098	-.142
60mLS	.107	-.064	-.137	-.166	-.046	.162	-.211	-.188	.212
20mLS	.256	.017	-.099	-.079	-.008	.078	-.144	-.171	.308+
20mFS	.036	-.020	-.049	-.164	.017	.158	-.166	-.171	.088
SR	-.292+	-.114	.018	.063	-.072	-.067	.109	.225	-.230
CT	.033	-.016	-.053	.006	-.112	-.009	.008	-.074	.070
FT	.194	.028	-.056	-.063	.045	.074	-.120	-.077	.183
LS	.296+	.127	.003	.079	.050	-069	.017	.027	.202
1.200	-.151	-.182	-.145	.003	-.210	-.003	-.011	.062	-.023
2.200	-.050	-.182	-.224	.019	-.209	-.023	.040	-.103	.158
Σ200	-.108	-.214	-.224	.009	-.245	-.012	.015	-.038	.095
SP_0	.094	.139	.151	-.027	.186	.030	-.044	-.038	-.032

Legend: + - p > 0,01 (.260)

The most significant tests of somatic factors are shown to be: body weight, relative body weight, active body weight (kg) and the ectomorphic component of the somatotype. These four indicators also show correlations with concurrent sports performance and other variables (decimal age, 50 m run from a high start, standing broad jump, medicine ball throw, 60 m and 20 m run from a low start, 20 m run from a flying start, stride frequency, contact and flight time and length of running step and 2x 200 m run. Of the somatically metric indicators, the relative body weight and mesomorphic tests show the most significant relationships. These tests also reach relatively high values of pair correlation coefficients with each other. After excluding the influence of decimal age by partial pair correlation analysis, the mentioned relations were slightly reduced, the body height indicator was highlighted, but overall the tendencies remained unchanged (tab 9).

Table 9 Partial correlation coefficients excluding decimal age between selected somatic and some other variables in group of girls

Tests	BH	BW	RelBW
BH		.497+	.135
BW			.919+
RelBW			
50mHS	.134	.053	-.022
SBJ	.061	.219	.249
60mLS	.154	.017	-.068
20mFS	-.082	.071	.034
SR	-.344+	-.210	-.059
CT	.054	.022	-.019
FT	.215	.066	-.029
LS	.309+	.153	.017
Σ200	-.032	-.067	-.086
SP_0	-.005	-.070	-.043

Legend: + - p > 0,01 (.260)

Somatic indicators do not show a significant correlation dependence to sports performances achieved with a time interval after CSP.

In the groups of girls, the decimal age variable shows a frequent and high relationship with a large number of variables, including the variables sports age and sports age in specialization. They show significantly less frequent pair correlation with other variables and not at all with sports performance. In the group of our girls, these relationships are less frequent, and even the pairwise correlation coefficients reach lower values. After excluding the influence of decimal age, the variables sport age and sport age in specialization correlate with the other variables only rarely (tab 10).

Table 10 Correlative coefficients between selected age and some other variables in group of girls

Tests	DA	SA	SASpe
DA		.066	.362+
SA			.235
SASpe			
50mHS	-.335	-.106	-.089
SBJ	-091	-.025	-.078
MBT	.102	.408+	.189
60mLS	-.202	.093	-.027
20mLS	-.071	-.108	.020
20mFS	-.214	-.016	-.024
SR	.192	-.095	.067
CT	-.094	.066	-.127
FT	-.080	-.018	-.090
LS	-.032	-.047	-.046
1.200	-.337+	.162	-.141
2.200	-.371+	-.004	-.054
Σ200	-.404+	.080	-.108
SP_0	.499+	.115	.203

Legend: + - p > 0,01 (.260)

From the battery of tests aimed at determining the level of general movement performance, the 50 m high start test shows the highest values of paired correlation coefficients. Significant relationships were expected with special motor performance tests (runs of 60 m and 20 m from a low start, 20 m from a flying start and with 2 x 200 m runs) and sports performance, because in this case (50mHS) we are dealing with a special test. The stated hypothesis 2a was confirmed for us in this part. Running 50 m from a high start shows significant relationships even with special motor dispositional tests (frequency, contact and flight time of the running step) (tab 11).

Table 11 Correlative coefficients between tests of general motor performance and some selected special motor tests and sport performance in group of girls

Tests	50mHS	SBJ	SFB	SU2min	BAH	MBT	12min	50mHS*	SBJ*
50mHS		-.078	-.147	-.005	-.121	-.107	.059		-.116
SBJ			.183	.082	.116	-.102	-.085		
SFB				.209	.297+	.190	.025		
SU2min					-.005	.175	.167		
BAH						.232	-.111		
MBT							-.096		
12min									
60mLS	.479+	-.264	-.094	.268+	-.103	.007	-.062	.446+	-.290
20mLS	.523+	-.327+	-.194	.215	-.276+	-.176	.098		
20mFS	.472+	-.307	-.026	.183	-.258	.078	.010	.436+	-.336+
SR	-.431+	.044	-.075	-.075	.154	-.174	.247	-.397+	.064
CT	.363+	-.166	-.113	.068	-.067	.132	-.027	.354+	-.176
FT	.071	.140	.100	.088	-.045	-.083	-.191	.048	.134
1.200	.427+	-.041	-.026	.275+	-.091	.011	-.104		
2.200	.475+	-.205	-.140	-.079	-.165	-.016	-.189		
Σ200	.522+	-.156	-.103	.085	-.158	-.005	-.177	.450+	-.212
SP_0	-.416+	.109	.139	-.166	.160	.094	.178	-.306+	.179

Legend: 1. + - p > 01 (.260)

*2. * - In these columns are stated partial correlative coefficients excluding decimal age*

Other tests of general motor performance correlate less often and the pairwise correlation coefficients are lower than in the 50 m high start test.

In the group of our girls, the standing broad jump to special motor tests of realization and disposition often shows a significant relationship. Exceeding the one percent level of significance also appears with sports performance (tab 12).

Tests for the depth of the forward bend, endurance in the curl on the bar, the number of sit-up repetitions and performance in a 12-min run show only a rare and relatively small exceedance of the critical level of significance. For girls, this is also the case with the medicine ball throw test. After excluding the influence of decimal age, the high informative value of the 50 m run test from a high start is confirmed (tab 12).

Table 12 Correlative coefficients between special motor tests realizable and special motor tests dispositional and sport performance in group of girls

Tests	60mLS	20mLS	20mFS	Tech	50mJR	1.200	2.200	Σ200
60mLS		.792+	.742+	-.434+	-.380+	.451+	.412+	.501+
20mLS			.569+	-.404+	-.350+	.346+	.284+	.364+
20mFS				-.371+	-.409+	.425+	.568+	.589+
Tech					.272+	-.453+	-.218	-.378+
50mJR						-.169	-.285+	-.273
1.200							.470+	.820+
2.200								.888+
Σ200								
SR	-.555+	-.471+	-.539+	.352+	.190	-.384	-.403+	-.457+
CT	.387+	.280+	.429+	-.358+	-.227	.382+	.356+	.425+
FT	.125	.247	-.059	-.037	.099	.168	-.053	.049
FT/CT	-.196	-.046	-.327+	.237	.237	-.128	-.285+	-.252
LS	-.059	.031	-.280+	.002	.146	.009	-.007	-.004
RelLS	-.180	-.178	-.348+	.008	.172	.108	-.011	.042
LS/CT	-.413+	-.267+	-.644+	.272+	.211	-.283+	-.410+	-.413+
ΣPF	-.154	-.101	-.260+	-.010	.146	-.019	-.182	-.137
SP_0	-.392+	-.347+	-.422+	.293+	.262+	-.453+	-.482+	-.543

Legend: + - p > 01 (.260)

In the group of special motor realization performance tests (running 60 and 20 m from a low start, running 20 m from a flying start, 50 m jump run and 2x 200 m) we find the expected mutual binding of these tests. Pairwise correlation coefficients mostly greatly exceed the one percent significance level. In the group of girls, a pairwise correlation at the 1% level of significance is also found with the tests length and relative length of the step and with the index of the length of the step divided to contact time of the running step (LS/CT). Most of these tests also show a significant relationship with concurrent sports performance. After excluding the influence of decimal age, there is a significant correlation between the 60 m run, 20 m run from flying start and 2x 200 m tests to other special motor tests, as well as to concurrent sports performance (tab 13).

Table 13 Correlative coefficients with exclusion of decimal age between some special motor tests realizable and some special motor tests dispositional and sport performance in group of girls

Tests	60mLS	20mFS	50mJR	Σ200
60mLS		.731+	-.349+	.469+
20mFS			-.377+	.562+
50mJR				-.197
Σ200				
SR	-.538+	-.520+	.151	-.423+
CT	.378+	.421+	-.212	.425+
FT	.112	-.079	.124	.018
FT/CT	-.197	-.332+	.242	-.269+
LS	-.067	-.294+	.159	-.020
SP_0	-.343+	-.368+	.167	-.431+

Legend: + - p > 01 (.260)

In the group of special motor dispositional tests, we observe often and relatively high mutual relationship (tab 14). The most important seem to be tests of frequency and contact time of the running step. In both sets, there are only rare statistically significant relationships to sports performances. When excluding the influence of decimal age using partial pairwise correlation, there are no significant changes (tab 15).

Table 14 Correlative coefficients between special motor tests dispositional and sport performance in group of girls

Tests	SR	CT	FT	FT/CT	LS	RelLS	LS/CT	ΣPF
SR		-.391+	-.510+	-.050	-.559+	-.283+	.132	-.001
CT			-.256	-.771+	-.011	-.049	-.557+	-.137
FT				.781+	.655+	.459+	.545+	.261+
FT/CT					.406+	.329+	.702+	.231
LS						.756+	.546+	.291+
RelLS							.505+	.298+
LS/CT								.208
ΣPF								
SP_0	.411+	-.264+	-.093	.138	-.066	-.103	.294+	.001

Legend: + - p > 01 (.260)

Table 15 Correlative coefficients with exclusion of decimal age between some special motor tests dispositional and sport performance in group of girls (n = 95)

Tests	SR	CT	FT	FT/CT	LS
SR		-.382+	-.506+	-.054	-.564+
CT			-.266+	-.773+	-.015
FT				.785+	.655+
FT/CT					.407+
LS					
SP_0	.372+	-.252	-.062	.151	-.058

Legend: + - p > 01 (.260)

Table 16 shows some pairwise correlation coefficients between sports performances. The self-predictive validity of sports performances is quite clearly manifested in our group of girls. This confirms hypothesis 2d.

Table 16 Coefficients of auto-predictive validity of variable sport performance in group of girls (n = 66)

	SP_1	SP_2
SP_0	.816+	.610+
SP_1		.736+

Legend: + - p > 01 (.317)

A basic pairwise correlation analysis confirms to us that tests that evaluate the same physical characteristics and abilities are logically related to each other. This mainly concerns somatic, speed, speed-strength and speed endurance tests. Tests of somatic and general motor performance (except for 50 m run from a high start, which in this case is a special test) rarely exceed the critical values of the one percent level of significance with sports performances. It is probably because our group that participated in CSP (specialized selection II) already have the optimal level of the mentioned factors and tests. We hereby confirm the well-known fact that somatic indicators and tests of general motor performance are optimally determining factors for short-distance running. Hypothesis 2b is thus confirmed.

Decimal age shows a significant correlation dependence with many variables. On the contrary, the variables sports age and sports age in specializations, which only exceptionally significantly correlate with the other variables, do not meet our expectations. This does not confirm hypothesis 2c.

Speed tests and tests aimed at determining the level of speed endurance are significantly correlated with sports performance. Of the speed-strength tests, the 50 m jump run (realization tests) is the most important test. Tests aimed at characterizing the kinematic structure of the running step (dispositional tests) often and significantly exceed mutually the critical values of the correlation relationship. It will probably also be due to the fact that some of them are derived. Significant relationships with sports performances occur only rarely and at a relatively low level. This does not confirm hypothesis 2a.

In Table 17, we compare some pairwise correlation coefficients between selected variables, individual disciplines and entire sets. We note that although the height of the pairwise correlation coefficients varies from discipline to discipline, the tendencies of these coefficients are quite similar. We have to state that for our group of girls, the tendencies of the pairwise correlation coefficients are not entirely clear. This may be due to their lower number as well as a higher degree of heterogeneity in terms of demands in girls' short distance running. Nevertheless, we believe that hypotheses 2a and 2b are again confirmed.

Table 17 Comparison of pair correlative coefficients between some variables, watched athletic disciplines and the whole group of girls

Disciplines	100 m	200 m	100 m H	400 m	400 m H	N
Numbers	n = 16	n = 28	n = 22	n = 16	n = 13	n = 95

Critical l. *	.622	.478	.536	.622	.683	.260
Variables	SP_0					
DA	.630+	.172	.674+	.796+	.361	.499+
SBJ	.655+	.134	-.098	-.188	.258	.109
60mLS	-.546	-.100	-.568+	-.405	-.704	-.392+
20mLS	-.647+	-.418	-.465	-.564	-.508	-.422+
SR	.689+	.182	.460	.428	.462	.411+
CT	-.702+	-.188	-.502	-.326	-.009	-.264+
LS	.075	.226	-.110	.120	-.318	-.066
50mJR	.246	.209	.287	.455	.059	.262+
Σ200	-.799+	-.408	-.711+	-.566	-.263	-.543+
	20mLS					
DA	-.660+	-.363	-.267	-.433	.344	-.214
SBJ	-.707+	-.181	-.325	-.061	-.131	-.307+
60mLS	.750+	.539+	.853+	.816+	.664	.742+
SR	-.679+	-.275	-.597+	-.495	-.573	-.539+
CT	.506	.201	.713+	.463	.094	.429+
LS	-.452	-.521+	-.097	-.442	.413	-.280+
50mJR	-.445	-.545+	-.486	-.727+	.029	-.409+
Σ200	.536	.485+	.782+	.596	.469	.589+
	50mJR					
DA	.294	.228	.116	.504	.176	.244
SBJ	.147	.384	.023	-.021	.340	.244
60mLS	-.540	-.108	-.622+	-.551	-.330	-.196
SR	.165	-.107	.257	.726+	.343	.190
CT	-.006	-.068	-.520	-.281	-.442	-.227
LS	.153	.526+	.217	-.046	-.473	.146
Σ200	-.358	-.193	-.384	-.343	-.483	-.273+

Legend: *+ - $p > 0.01$*

In Table 18, we compare the pairwise correlation coefficients between some test items and sports performance in the CSP season expressed in absolute values, that is, in seconds. We can see that the coefficients calculated from the absolute values hardly differ from those calculated from the point values. This applies to both groups. This clearly confirms hypotheses 2a and 2b.

Table 18 Comparison of pair correlative coefficients between some variables and final sport performances in watched athletic disciplines in groups of girl

	Final sport performance				
Disciplines	100 m	200 m	100 m H	400 m	400 m H
Numbers	n = 16	n = 28	n = 22	n = 16	n = 13
Critical l. *	.622	.478	.536	.622	.683
DA	.525	.026	.257	.506	-.069
SBJ	.398	.134	.172	-.035	.698+
60mLS	-.330	-.285	-.593+	-.144	-.711+
20mLS	-.449	-.610+	-.525	-.230	-.487
SR	.583	.077	.284	.253	.294
CT	-.621	-.263	-.672+	-.286	-.020
LS	-.116	.387	.202	-.084	-,100
50mJR	.017	.253	.488	.362	.037
Σ200	-.589	-.286	-.556+	-.346	-.258

Legend: *+ - p > 01*

4.2.1 Long-term prediction of sports performance in short-distance running

The prediction of sports performance, either definitive (maximum) or for a certain period of time, is closely related to the issues of selecting talented individuals. The theoretical elaboration of the problem of prediction is supported by a whole series of empirical research works, the results of which are, however, ambiguous and contradictory in many ways (Havlicek, 1986). It is confirmed that the predictive validity of the selected indicators increases with the shortening of the prediction time factor (Havlicek, 1974; Havlicek et al., 1987) and logically also with increasing homogeneity of the set, or with a lower number of monitored probands, or in case when independent and dependent variables are very similar (Andrade, Figueira Jr, Amadio, Serrão (2019).

In our work, we rely on knowledge of selection results (CSP) and subsequent long-term monitoring of sports performance. The aim of this chapter is to select sports performance prediction equations that would be applicable in practice at the level of coaches and researchers and would be sufficiently reliable with an acceptable estimation error. In our set of girls, the number of probands also decreased with the increasing time interval, and the number of our variables exceeded the program capabilities of the computing technology we used. Therefore, we used the method of multiple stepwise correlation and regression in two waves. In the first one, we monitored the development of addiction to individual sports performance in individual subsets separately according to groups of variables (somatic, age, general sports performance, special motor - realization and special motor - disposition). In this way, we identified variables with a long-term higher relationship to sports performance and separated and excluded variables with a low contribution to the explanation of sports performance. On this reduced set of variables, we performed the second wave of multiple stepwise correlation and regression, the results of which we used in selecting suitable prediction equations.

In the first wave of multiple stepwise regression, differences in the frequency of relations and their weight between individual variables are shown (tab 19). For boys (Sedlacek, 1994), special motor variables - realization and disposition appear to be the most significant. In case of girls decimal age and 50 m high start tests appear frequently and with a relatively large weight, which in this case is a special test. Other variables - age, special movement performance and somatic appear less often and their explanatory weight is generally not too high.

In the second round of multiple stepwise regression, we took all the variables that showed increased dependence at least once in the first round (tab 19). We included 13 variables in the second round of stepwise regression of our group. This resulted from the analysis of the first part of the stepwise regression, where there are fewer variables with sufficient explanatory weight in girls group.

Table 19 First wave of stepwise regression – variables showing the highest dependence in the observed period

Groups of variables	SP_1	SP_2	SP_3	SP_4	** 2nd wave
	n = 77	n = 66	n = 52	n = 31	
Somatic v. *	-	-	ABWkg	-	ABWkg
Age v.*	DA	DA	SA	DA, SA	DA, SA

GMP v. *	50mHS, SU2min	50mHS, SU2min	50mHS,	50mHS, SU2min	50mHS, SU2min
SMR v. *	20mLS, Σ200	20mLS	Tech	20mLS, Tech	20mLS, Tech, 50mJR, Σ200
SMD v. *	SR, LS, LS/CT	LS/CT, SR	LS/CT, ΣPF	LS/CT	SR, LS, LS/CT, ΣPF

*Legend: * - groups of somatic, age, general motor performance (GMP v.), special motor realizable (SMR v.), special motor dispositional (SMD v.) variables.*

*** - selected variables to 2nd wave of stepwise regression*

The results of multiple step correlation and regression are shown in tables 20, 21, 22 and 23. Table 24 shows selected conversions between points and seconds in individual disciplines, so it is possible to specify the error of estimation, which is given in points. When selecting and including the reduced sets in the tables, we took into account, in particular, the absolute values of the coefficients of multiple correlation and determination, the mean estimation error, the value of the F-test and the applicability of the set in field conditions (for coaches and educators) or partly with the use of more demanding measuring technicians (researchers).

In our group of girls, the situation is quite different from the groups of boys, also participants in CSP (Sedlacek, 1994); this mainly concerns the number of presented reduced sets for predicting subsequent sports performance. This is due to the smaller number of this group and also to the earlier abandonment of sports after CSP. Boys play sports on average 3.25 years after selection, while girls only 2.62. These baseline conditions limited the number of prediction equations for girls as well as the time length of predictions of future sports performance.

Table 20 shows 4 reduced sets (a-d) for predicting sports performance with a time lapse of 1 year after testing. Numbers in sets are given by how many girls raced one year after CSP (n = 94); set b), where the number is n = 66, is a set where girls still raced 2 years after CSP, analogously, set c) still raced 3 years after CSP and set d) still raced 4 years after CSP. The listed sets of equations can be considered acceptable from the point of view of use in practice, even if they require either anthropometric examinations (a, b, c) or expert assessment of sprint running technique (d). Other variables are commonly used tests in practice.

Table 20 Multiple correlation and regression of a reduced sets of variables to sports performance with a one-year interval (SP_1) after central selection procedure (CSP):

a) n = 94

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
ABWkg	-.247	.005	-5.597	2244.520
DA	.314	.116	20.460	
20mLS	-.291	.121	-211.145	
Σ200	-.280	.123	-11.170	
		R^2= .370		
		R = .608		
		S_R = 68.440		

b) n = 66

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
ABWkg	-.197	-.012	-4.511	2312.545
DA	.309	.128	19.504	
SU2min	-.130	.036	-.693	
20mLS	-.284	.124	-211.857	
Σ200	-.304	.148	-11.829	
		R^2= .424		
		R = .651		
		S_R = 66.5		

c) n = 52

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
ABWkg	-.233	-.005	-5.524	2038.700
DA	.273	.120	18.044	
SU2min	-.216	.073	-1.300	
Σ200	-.483	.252	-18.316	
		R^2= .441		
		R = .664		
		S_R = 67,8		

d) n = 31

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
SA	.224	.042	7.233	2216.964
SU2min	-.237	.084	-1.208	
20mLS	-.287	.198	-179.132	
Tech	.183	.109	20.684	
Σ200	-.373	.225	-11.462	
		R^2= .659		
		R = .812		
		S_R = 47.7		

For the prediction of sports performance for 2 years after the testing (tab 21), a more demanding measuring technique (locomometer) is required in two cases (a, b). In the third case, we do without a demanding measuring technique, but the set has 5 tests and is calculated on a group of 31 probands. It is necessary to consider which of the presented alternatives is optimal for a specific case.

Table 21 Multiple correlation and regression of a reduced sets of variables to sports performance with a two-year interval (SP_2) after central selection procedure (CSP):

a) n = 66

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
20mLS	-.369	.162	-269.103	1718.086
LS/CT	.256	.096	146.391	
ΣPF	-.161	.012	-.597	
		R^2= .270		
		R = .519		
		S_R = 72.1		

b) n = 52

Tests	$B_{i.k}$	$B_{i.k}\, r_{i.k}$	$b_{i.k}$	a
SU2min	-.206	.054	-1.151	1609.340
20mLS	-.283	.118	-217.969	
LS/CT	.276	.103	168.249	

ΣPF	-.191	.021	-.725	
		R^2= .298		
		R = .546		
		S_R = 70.1		

c) n = 31

Tests	$\mathbf{B_{i.k}}$	$\mathbf{B_{i.k}\,r_{i.k}}$	$\mathbf{b_{i.k}}$	**a**
SU2min	-.298	.102	-1.469	2036.505
20mLS	-.380	.237	-228.947	
50mJR	.398	.179	23.370	
ΣPF	-.446	.011	-1.711	
Σ200	-.172	.077	-5.116	
		R^2= .608		
		R = .779		
		S_R = 49.5		

For the prediction of sports performance for a period of 3 and 4 years after testing, we present 3 sets (tabs 22 and 23). The mentioned sets assume the use of more demanding measuring devices (locomometer).

Table 22 Multiple correlation and regression of a reduced sets of variables to sports performance with a three-year interval (SP_3) after central selection procedure (CSP):

a) n = 52

Tests	$\mathbf{B_{i.k}}$	$\mathbf{B_{i.k}\,r_{i.k}}$	$\mathbf{b_{i.k}}$	**a**
ABWkg	-.243	.062	-6.280	1919.543
SU2min	-.146	.035	-.960	
20mLS	-.303	.131	-275.352	
LS/CT	.306	.141	219.722	
		R^2= .371		
		R = .609		
		S_R = 78.5		

b) n = 31

Tests	$B_{i.k}$	$B_{i.k}\,r_{i.k}$	$b_{i.k}$	a
SA	.148	.040	4,863	934.426
20mLS	-.352	.208	-223.477	
Tech	.220	.110	25.228	
LS/CT	.229	.138	125.813	
ΣPF	-.286	-.012	-1.156	
		R^2= .656		
		R = .810		
		S_R = 49.8		

Table 23 Multiple correlation and regression of a reduced sets of variables to sports performance with a four-year interval (SP_4) after central selection procedure (CSP):

a) n = 31

Tests	$B_{i.k}$	$B_{i.k}\,r_{i.k}$	$b_{i.k}$	a
20mLS	-.500	.302	-358.370	1931.570
LS/CT	.392	.224	-243.141	
ΣPF	-.238	.001	-1.084	
		R^2= .527		
		R = .726		
		S_R = 62.2		

Table 24 Converting points to seconds at a performance level of 950 points in group of our girls (Spiriev, Kovacs, 1987)

	Disciplines				
Points	100 m (s)	200 m (s)	100 m H (s)	400 m (s)	400 m H (s)
10	.05	.12	.10	.24	.40
20	.10	.24	.20	.48	.80
30	.15	.36	.30	.72	1.20
35	.175	.42	.35	.84	1.40
40	.20	.48	.40	.96	1.60
45	.225	.54	.45	1.08	1.80
50	.25	.60	.50	1.20	2.00

55	.275	.66	.55	1.32	2.20
60	.30	.72	.60	1.44	2.40
65	.325	.78	.65	1.56	2.60

In our group of girls, only 13 variables entered the second wave of multiple correlation analysis (tab. 19), in contrast to 25 variables in boys (Sedlacek, 1994). The test of 20 m from a low start appears most often in our 10 selected sets, in 9 cases. Other tests occur very often, that is from 3 to 6 repetitions. It includes active body weight, decimal age, number sit-ups, index length to contact time of the running step, average plantar flexion of the lower limbs and test 2x 200 m. The remaining tests occur rarely. It is especially striking in the tests of 50 m from a high start, frequency and length of step and 50 m jump run.

For girls, mostly 6 variables enter the multiple stepwise correlation analysis, which significantly explain future sports performance. The presented results of the multiple correlation analysis confirm the determination of sports performance in short-distance running by the level in tests of special motor performance (hypothesis 2a). The determination of sports performance by the level in tests of special motor disposition was not confirmed to us to the extent that we expected in the subject hypothesis. The level of determination of sports performance in the indicators of strength, technical readiness and physical development were above our expectations, especially in the case of technical readiness. We managed to present a relatively large number of prediction equations, which can be used for the needs of athletic practice at two levels: at the level of a coach or educator in the field and at the level of researchers using more demanding measuring techniques. We believe that hypothesis 3 has been confirmed.

5 Summary and conclusions

5.1 Summary

1. As part of solving the first task, we managed to contribute to the explanation of the importance of the level of strength abilities and flexibility in the realization of sports performance in the 400 m hurdles. We demonstrated significant relationship of strength readiness tests on sports performance, as well as on each other. The most important of the tests used was the 50 m jump test. Compared to strength readiness tests, flexibility tests were fundamentally less significant. Through multiple rank correlation and regression, we were able to explain 59.7% of the sports performance in the 400 m hurdles with strength readiness tests. By examining other variables, especially performance variables, we managed to identify relationships between these variables and tests of strength readiness and flexibility. Using these additional variables in multiple correlation and regression models allowed us to explain the performance of the dependent variable in the 400m hurdles up to 99.9%. With the mentioned procedures, we contributed to a deeper clarification of the relationships between the variables in the structure of sports performance in men's 400 m hurdles.

Based on the reduced matrix, we can construct a regression equation for predicting sports performance in the 400 m hurdles:

$$Y = 1.115 + 0.978\, x_1 + 1.003\, x_2 - 0.004\, x_3 \pm 0.045$$

with 99.9% probability where

Y = predicted power /s/

x_1 – technique and rhythm index /s/

x_2 – performance on 400 m smooth /s/

x_3 – forward bend in obstacle seat /s/

Based on the identified factors, we recommend the following standards for evaluating the flexibility and strength readiness indicators necessary to achieve the I. performance class level:

- lean forward: 15-20 cm,
- spread angle: 130 – 150°,
- forward bends in obstacle sitting:
  - dominant (swing) lower limb: 16 – 22 cm,
  - non-dominant lower limb: 13 – 19 cm,
- ten jumps: 28.50 – 30.50 m,
- standing broad jump: 265-280 cm,

- index of 50 m jump run: 2.80 and below,
- 10 repetitions sit-ups: 12 s and better,
- 30 repetitions sit-ups: 37 s and below,
- pull-ups: 10 and more.

2. By solving the second task, we found that the results of the pairwise and multiple correlation analysis confirm the high informativeness of the special motor realization performance tests. The tests in the 20 m run from a low start and the 50 m jump run measured by an electronic timer, which ensures high measurement accuracy, seem to us to be the most important.

The similarity of correlation relationships when analyzing individual disciplines separately (100 m, 200 m, 100 m H, 400 m and 400 m H) confirms that it is a group of disciplines with a similar structure of sports performance. That's why the names that are commonly used - running on short distances, or athletic sprints including all the mentioned disciplines are to be justified.

We expected a more frequent representation and a higher explanatory weight in the prediction equations in special motor tests of dispositions, which are considered to be developmentally stable in human ontogeny, or conservative (Kampmiller, 1984; Vanderka, Kampmiller, 2013). We explain their low representation and explanatory weight by the fact that they are included in higher-order factors, which in our case are tests of special motor performance, which thus take over their explanatory weight.

The expert evaluation of sprint running technique by coaches appeared surprisingly often in the sets of prediction equations. Due to the fact that in the paired correlation analysis, this indicator did not correlate with the other variables at all, we believe that it affects those aspects of the athlete's performance that we assessed only a little with our battery. It will probably relate to psychological processes and the process of motor learning. This also confirms the well-known fact that the visual anamnesis of an experienced trainer has its justification even in the higher stages of selection.

Among the other indicators, as expected, decimal age, tests of general motor performance – running for 50 m from a high start, standing jump and throwing a medicine ball and some somatic indicators show high informativeness. These variables appear quite often in prediction equations.

Pairwise and multiple correlation analysis and regression confirm the well-known phenomenon that research monitoring and subsequent evaluation shows more clearly interpretable results in the group of boys (Sedláček, 1994) than in our group of girls. Based on our results, we recommend using prediction equations to calculate subsequent sports performance in group of girls for 1-2 years. We consider a prediction for a longer period of time to be risky, especially from the point of view of the size of the forecast error.

We have confirmed that young people who play sports with a focus on short-distance running have a certain optimal level in the factors of body height and weight, which is mostly above the population norm. They are well above the population average in the factors of general motor performance. Therefore, somatic indicators and tests of general movement performance must be considered mainly from the point of view of reaching their optimal level.

We recommend that specialized selection II for short distance running take more into account the results achieved in the special motor tests of execution and disposition listed in order of importance:

a) a 20 m run from a flying start and a 50 m jump run,
b) running for 20 m from a low start, running for 2x200 m repeatedly, stride length, relative length step, index length of the stride to contact time of the running step and the flight time of the running step,
c) contact time of the running step, step frequency (rate), index flight time divided to contact time running step and the average of plantar flexions of the lower limbs.

At the same time, expert assessment of athletic sprint technique and decimal age must also be taken into account and given the same importance as in the case of the indicators listed in paragraph b).

We recommend that, at the same time as the mentioned testing, a more thorough anamnesis of previous sports training is carried out, aimed at revealing inappropriate dosage in special training means. Evident overdosing of these means should be considered as a suppressor of achieving high sports performance.

5.2 Conclusions

1. From the point of view of the tests of strength preparation monitored by us, it was possible to explain the sports performance in the 400 m hurdles to 59.7%. The most suitable test for assessing the strength readiness of the lower limbs is the 50 m jump run.

The structure of performance in the 400 m hurdles is made up of two basic factors: the special endurance factor in the 400 m smooth run and the technique and rhythm factor.

Reduced sets of flexibility and strength readiness explained the performance on 400 m smooth from 45.3%. It can be assumed that the performance in the 400 m smooth run can be explained with high probability on the basis of the level of indicators of flexibility, strength readiness, speed and speed endurance. However, the structure of the technique and rhythm factor is significantly more complex and includes, in addition to all motor abilities and skills (conditioning and coordination), also morphological and psychological factors. Even though we counted on the possibility of compensating the factors affecting sports performance, we can't just rely on flexibility and strength when clarifying the structure of the factors of technique and rhythm.

2. The closest correlations are found in self-prediction coefficients of sports performance. We have proven their high predictive validity and stability over time for special motor performance tests. On the contrary, in special motor disposition tests, we explain their low predictive validity by the fact that these variables are utilized in factors of a higher order, that is also in special motor realization tests.

Composite predictive validity shows higher values than simple. The presented prediction equations enable long-term prediction of sports performance in short-distance running.

3. The presented work provides a comprehensive view of some aspects of the issue of selection and prediction of sports performance in athletic sprints. We consider the explanation of the significance of indicators of special motor performance in tests of realization and disposition in the long-term prediction of sports performance to be a new insight. The work expands knowledge about the possibilities of long-term prediction in short-distance running.

It is necessary to connect the development of subsequent achieved sports performance, especially at a younger age, with the evaluation of the quality of the training process, or with an evaluation of the quantitative use of special training means.

4. Conclusions for use in sports practice.

We present indicative standards of strength readiness and flexibility in men's 400 m hurdles.

We propose an innovation of the selection procedure for girls in short-distance running at the level of the specialized selection stage II.

We present prediction equations for the long-term prediction of sports performance in short-distance running using simple diagnostic procedures suitable for off-road use and also we present equations with the possibility of using more demanding measuring devices that generally refine predictions.

The results of the research show that in short-distance running, in addition to special tests, it is also necessary to have an optimal level of somatic prerequisites and a level of performance in tests of general motor performance.

References

Aahper, (1965). Youth Fitness Test Manual. 3rd edition. Washington.

Ahmetov, I.I., Fedovskaja, O.N. (2015). Current progress in sport genomics. Adv Clin Chem, 70, p. 247-314.

Alabin, V.G. (1974). Beg na korotkije distancii (Short distance running). In: Učis begať, prygať, plavať. Minsk, Belarus.

Alabin, V.G., Juškevič, T.P. (1977). Sprint. Minsk, Belarus.

Alabin, V.G. (1981). Mnogoletnaja podgotovska legkoatletov (Long-term preparation of athletes). Minsk. Vyšejšaja škola.

Ambroš, Š.P. a kol. (1978). Ekonomika podniku. Vysokoškolské skriptá. Bratislava, VŠE.

Anderson, B. (1983). Streching. Bolinas, California, Shelter Publications.

Andrade R., M., Figueira Jr A., J., Amadio A., C., Serrão J., C. (2019). Prediction of 100 m sprint performance based on field test. Rev Bras Med Esporte. Vol. 25, No 4, p. 349-353.

Artjušenko, A. (1976). Meždu barjerami za sekundu (Between hurdles in one second). Leg. Atlet., 9, p. 19.

Aule, R., Loko, J. (1983). Selection of Young Athletes. Med. Athl. Coach, 21, 4, p. 3-6.

Babic, V., Blazevic, I., Katovic, D. (2012). Model of tests for assesment of sprint running proficiency. Science, Movement and Health Vol. Xii, Issue 2, 2012, Romania. Ovidius University Annals, Series Physical Education and Sport, p. 115-120.

Bačvarov, M. (1976). Bjeganie na 100 i 200 metra (100 and 200 m running). 1. vyd. Sofia, Medicina i kultura.

Baker, J., Wattie, N., Schorer, J. (2018). A proposed conceptualization of talent in sport. The first step in a long and winding road. Psychology of Sport and Exercise 43, p. 27-33.

Bakytová, H. et al. (1979). Základy štatistiky (Basics of statistics). Bratislava, Alfa.

Bauersfeld, K.H., Schröter, G. (1979). Grundlagen der Leichtatletik (Basics of athletics). Berlin, Sportverlag.

Baughman, M., Takahe, M. (1984). Sprint Training – Including Strength Training. Track and Field Quarterly Review, summer, p. 6-8.

Baur, J. (1988). Talentsuche und Talentförderung im Sport (Talent search and talent promotion in sport). Eine Zwischenbilanz (1. Teil). Leistungsport, 18, 2, p. 5-10.

Billouin, A. (1985). Athletisme (Athletics). Paris, Ed. Robert Laffont, 268 p.

Bláha, P. a kol. (1986). Antropometrie československé populace - Československá spartakiáda 1985 (Anthropometry of the Czechoslovak population - Czechoslovak Spartakiad 1985). Praha, Metasport.

Bloom, B. S. (1985). Developing Talent in Young People. New York, Ballantine.

Bogdanov, C. (1974). Kakim byť sprinterom (How to become a sprinter? Leg. Atlet. 9, p. 10.

Bosco, C., Vittori, E. (1986). Biomechanical Characteristics of Sprint Running during Maximal and Supramaximal Speed. New studies in Athletics, 1, p. 39-45.

Bosco, C., Vittori, E., Matteucci, E. (1985). Considerationi sulle variazioni dinamiche di alcuni parametri biomeccanici nella corsa. Atletica studi, 2, p. 147-154.

Brar, G. S. (1985). Comperative Effects of Circuit Training and Interval Training os Selected Physiological Measurements and Running Performance of Females. Thesis to Ph.D., Panjab University (India).

Bred, C., Rahmani, A., Dufour, B. A., Messonnier, L., Lacour, R. J. (2002). Leg strength and stiffness as ability factors in 100 m sprint running. J Sport Med Phis Fitness 42, 3, p. 274-81.

Brejzer, V., Ivkin, G. (1981) Problemy vynoslivosti v barjernom bege (Endurance problems in hurdling). Leg. Atlet. 12, p. 8-9.

Broom, E. F. (1991). Lifestyles of Aspiring High Performance Athletes: A Comparison of National Models. In: Journal of Comparative Physical Education and Sport XIII, 2, p. 24-55.

Bulančik, E. N. (1955). Barjernyj beh na 110 metrov (110 m hurdling). Moskva, FiS.

Bulgaková, N. Ž., Voroncov, A.R. (1978). O prognosirovanii sposobnostnej v plavanii na osnove longItudinalnych issledovanij (About prognostication of swimming ability on the basis of longitudinal studies). Teor. Prakt. Fiz. Kuľt., 41, 7, p. 37-40.

Bulgaková, N. Ž. (1978). Odbor i podgotovka junych plovcev (Selection and preparation of young swimmers). Moskva, FiS.

Bulgaková, N. Ž., Voroncev, A.R., Čerkasova, A. J. (1980). Primenenie longitudinalnych issledovanij v sportivnoj pedagogike scelju prognosirovanija fizičeskogo rozvitija i sportivnych dostiženij (Application of longitudinal studies in sports pedagogy for the purpose of forecasting physical development and sports achievements). Teor. Prakt. Fiz. Kuľt., 45, 8, p. 27-31.

Bulgaková, N. Ž. et al. (1984). Vremja utreždenija osnovy otbora i podgotovki (Time of determining the basis of selection and preparations). Teor. Prakt. Fiz. Kuľt , 5, p. 20-22.

Caha, J., Moravec, P. et al. (1984). Základní programový materiál běhu na 400 m překážek mužů a žen. (Basic program material for men's and women's 400 m hurdles). VMO ÚV ČSTV, Ostrava, Metasport.

Chauhan, M. (1989). Comparative Study of Somatotype, Motor Fitness and Selected Physiological Variables of Sports and Nonsports Girls at Different Altitudes. Thesis to Ph.D., Panjab University (India).

Choutka, M. (1973). Didaktika sportu – teorie sportovního tréninku a soutěžení (Sports didactics - theory of sports training and competition). Praha, SPN.

Choutka, M. (1976). Studium struktury sportovních výkonů (Study of the structure of sports performance). Praha, KU.

Cornett, Z., Lyle, B. (1977). Maximum Speed of Women Sprinters. Track Techn. June, p. 2160.

Counsilman, J. (1976). Power: What is it and how to use it. Track Techn. 64, p. 2031.

Černeva, L. (1971). I skorosť i technika (Speed and Technique, too). Leg. Atlet. 12, p. 15.

Defrise, E., Susanne, C. (1978). Multivariate Analysis in Twin Studies. In: Twin Research, Psychology and Methodology, Alan R. Liss, Inc, New York, N.Y. p. 234-237.

De Garay et al. (1974). Genetic and Anthropological Studies of Olympic Athletes. New York, San Francisko, London, Academie Press.

Dimitrov, K. G. (1964). Bjaganija prez prepjatstvija (Hurdling running). Sofija, Medicina i fizkultura.

Dobrý, L. (1983). Didaktické základy sportovního tréninku (Didactic basics of sports training). Učební texty TŠ ČÚV ČSTV. Praha, Olympia.

Dostál, E. et al. (1965). Překážkový běh na 110 m (110 m hurdling). In: Technika lehkoatletických disciplín. Praha, SPN.

Dostál, E. et al. (1969). Jednotný tréningový systém pro hladké a překážkové běhy mužů a žen na krátkych tratích (Uniform training system for men's and women's smooth and obstacle runs on short courses). Praha, Olympia.

Dostál, E. (1972). Běh mužů na 110 m překážek (Men's 110 m hurdles. In: Technika lehkoatletických disciplín. Praha, SPN.

Dostál, E. (1975). Nové zahraniční poznatky o atletickém tréninku – sprinty (New foreign knowledge about athletic training – sprints). Metodický dopis, Praha, ÚV ČSTV.

Dostál, E. (1985). Sprinty (Sprints). In: Atletika do kapsy, svazek 5. Praha, Olympia.

Dovalil, J. et al. (1982). Malá encyklopedie sportovního tréninku (A small encyklopedia of sports training). Praha, Olympia.

Dovalil, J. (1986). Pohybové schopnosti a jejich rozvoj ve sportovním tréninku (Movement abilities and their development in sports training). Studijní materiály pro doškolování ve vrcholovém sportu. Praha, ÚV ČSTV.

Dovalil, J. et al. (2002). Výkon a trénink ve sportu (Performance and training in sports). Praha, Olympia.

Dovalil, J. et al. (2009). Výkon a tréning ve sportu (Performance and training in sports). Praha. Olympia.

Dovalil, J. et al. (2012). Výkon a trénink ve sportu (Performance and training in sports). Praha, Olympia, p. 336. ISBN 978-80-7376-326-8.

Dreke, B. (1982). Skúsenosti z výberu talentovaných detí a mládeže na tréning vo výkonnostnom športe (Experience in selecting talented children and youth for training in performance sports). In: Výber a príprava športovo talentovanej mládeže. ÚV ČSZTV, Vedecká rada – materiály z celoštátnej vedeckej konferencie v Bratislave 11. - 13.6.1982, Bratislava, Šport.

Dudarev, I. L., Plachtijenko, V. A. (1975). Kak stať siľnym, smely i lovkim (how to become strong, brave and smart). Moskva, VIMO.

Dyško, B.A., Kravcev, I.N. (1987). Biodinamika bjega s maximalnym uskorenijem (Biomechanics of running with maximal acceleration). Teor. Prakt. Fiz. Kuľt. , 8, p. 38-40.

Ďjačkov, V.M. (1972). Soveršenstvovanije techničeskogo masterstva sportsmenov (Technique mastering perfection of sportsmen. Moskva, Fis.

Eiben, O.G. (1972) The Physique of Women Athletes. The Hungarian Scientific Council of Physical Education, Budapešť.

Falbriard, M., Mohr, M., Aminian, K. (2020). Hurdle Clearance Detection and Spatiotemporal Analysis in 400 Meters Hurdles Races Using Shoe-Mounted Magnetic and Inertial Sensors. Sensors 2020, 20, 354; doi:10.3390/s20020354.

Farfeľ, V.S. (1960). Fiziologija sporta (sport physiology). Moskva, Fis.

Filin, V.P. (1974). Vospitanije fizičeskich kačestv u junych sportsmenov (Education of physical qualities of young athletes). Moskva, FiS.

Filin, V.P., Fomin, N.A. (1980). Osnovy junočeskogo sporta (Basics of youth sports). Moskva, FiS.

Fisher, R.J., Borms, J. (1990). The Search for Sporting Excellence. Schrondorf, Hoffmann Verlag, 93 p.

Fremer, M. a kol. (1977). Základy politickej ekonómie. Bratislava, Pravda

Gajdarska, P.M., Siris, P.Z. (1976). Eksperimentalna metoda naboru i prognozovania rozvoju mlodych sprinterov (Experimental method of recruiting and forecasting the development of young sprinters). Lekkoatletyka, 21, 6, príl.: Szokolenie i trening 60, p. VI-VIII.

Gedda, L. et al. (1966). Ricerche medicobiologicke sugli atleti olympionici ai Giochi di Roma (Medicobiological research on Olympic athletes at the Rome Games). Med. Sport (Torino), 8, p. 477-484.

Glesk, P. (1972). Závislosť výkonnosti v behu na 100 a 200 m na štruktúre tréningových prostriedkov v jednoročnom tréningovom cykle pretekárok širšieho reprezentačného družstva ČSSR (Dependence of performance in 100 and 200 m running on the structure one-year training cycle of female athletes of the wider representative team ofthe Czechoslovak Republic). Kandidátska dizertačná práca, Bratislava, KTV EF SVŠT.

Gooden, K. (1979). The Relationship of Selected Anthropometric Measurements of the Leg and Foot to Speed and Vertical Jump of Male Collegiate Track and Field Athletes. Completed Research in Health, Physical Education and Recreation, 21, p.307.

Gorbenko, V., Smirnov, A. (1980). Racionalizacija trenirovok barjeristov (Rationalization of training for hurdlers). Leg. Atlet. 3, p.13.

Gralka, H. (1964). Biegi przez plotki (Hurdling running). Warszawa, Sport i turystyka.

Grasgruber, P., Cacek, J. (2008). Sportovní geny (Sports genes). Brno, Masarykova univerzita, FSPS.

Grebe, H. (1956). Die Biologischen Grundlagen der sportlichen Leistungsfähigkeit (The biological basis of athletic performance). Frankfurt/Main.

Guilford, J.P. (1964). Podstawowe metody statystyczne w psychologii i pedagogike (Basic statistical methods in psychology and pedagogy). Warszawa PWN.

Gužalovskoj, A.A. (1977). Fizičeskoje vospitanie školnikov v kritičeskie periody rozvitija (Physical education of pupils in critical periods of development). Teor. Prakt. Fiz. Kuľt. 40, 7, p. 37-39.

Hamar, D., Tkáč, M. (1990). Erfassung der anaeroben alaktaziden Leistung mittels einfaches Sprungergometers (Recording of the anaerobic alactic performance using a simple jumping ergometer). Leistungssport 20, 1, p. 19-23.

Harre, D. et al. (1973). Nauka o sportovním tréninku (The science of sports training). Praha, Olympia.

Harsányi, L., Martin, M. (1983). Zur Auswahl sportlicher Talente (To select sporting talents). Leistungssport, 13, 2, p. 21-24.

Havlíček, I. (1968a). Závislosť medzi ľahkoatletickou výkonnosťou a všeobecnou telesnou výkonnosťou u pohybovo nadaných žiakov ľahkoatletických experimentálnych škôl (Dependence between athletics performance and general physical fitness in physically gifted students of athletics experimental schools). Teor. Praxe těl. Vých. 17, 7, p. 440-444.

Havlíček, I. (1968b). Výber kritérií pre ľahkú atletiku na základe analýzy telesnej výkonnosti (Selection of criteria for athletics based on physical performance analysis). Rigorózna práca. Bratislava, FTVŠ.

Havlíček, I. (1973). Výber talentovanej mládeže pre ľahkú atletiku (Selection of talented youth for athletics). Metodický list 2, Bratislava, Šport.

Havlíček, I. (1974). Predikčná validita pohybových schopností všestrannej atletickej výkonnosti (Predictive validity of movement skills of general athletic performance). Teor. Praxe těl. Vých. 22, 9, p. 539-545.

Havlíček, I. (1975). Metodologické východiská štúdia štruktúry a predikcie športového výkonu (Methodological starting points for the study of the structure and prediction of sports performance). In: Acta fac. educ: phys. Univ. Comenianae XVII. Bratislava, SPN, p. 91-110.

Havlíček, I. (1980). Obratnosť (Dexterity). In: Telesná príprava športovcov. Rozvoj pohybových schopností. Bratislava, Šport, p.129-147.

Havlíček, I. (1982a). Systém športovej prípravy talentovanej mládeže v ČSSR (System of sport talented preparation of Czechoslovak youths). Tréner, č. 6, p. 242.

Havlíček, I. et al. (1982b). Vedecké základy športovej prípravy mládeže. (Scientific foundations of youth sports training). Zborník VMR SÚV ČSZTV IX. Bratislava, Šport.

Havlíček, I. (1983). Empirický výskum v športe (Empirical research in sport). In: VII. zborník telovýchovnej školy SÚV ČSZTV, k metódam skúmania v športe. Šport, p. 11-44.

Havlíček, I. (1986). Aktuálne prístupy vo výbere a tréningu športovo talentovanej mládeže (Current approaches in the selection and training of athletically talented youth). VÚV ČSTV, vědeckometodické oddělení, Praha, Olympia.

Havlíček, I. et al. (1987). Športová príprava talentovanej mládeže (Sports training of talented youth). Zborník VM Rady SÚV ČSTV, Bratislava, Šport, 328 p.

Havlíček, I. (1990). Efektivita výberu a športovej prípravy talentovanej mládeže (Effectiveness of selection and sports training of talented youth). Čiastková úloha ŠPTR N 01-333-801/03. Bratislava.

Hemery, D. (1986). Sporting Excellence, A study of Sport´s Highest Achievers. London, Willow Books.

Heyward, V.H., Ellis, S.M., Romer, J.F. (1986). Gender Differences in Strenght. Research Quarterly for Exercise and Sport. 57, 2, p. 154-159.

Hirtz, P. (1977). Struktur und Entwicklung koordinativer Leistungsvoraussetzungen bei Schulkindern. (Structure and development of coordinative performance requirements in school children). Theor. Prax. Körperkult. 26, 7, p.503-510.

Hirtz, P. et al. (1985). Koordinative Fahigkeiten im Shulsport (Coordinative skills in school sports). Berlin, Volk und Wissen Volkseigener Verlag.

Hirtz, P. (2007). Phanomene der motorischen Entwicklung des Menchen (Phenomena of human motor development). Schondorf, Hofmann.

Hlína, J., Adamčíková, R. (1989). Analýza oporné a letové fáze bežeckého kroku (Analysis of the contact and flight phases of the running step). In: Atletika, 41, 10, p. 17-19.

Holček, R. et al. (1991). Kinematická charakteristika behu šprintérov v prirodzených a zľahčených podmienkach (Kinematic characteristics of sprinters' running in natural and easier conditions). In: Referát na medzinárodnej konferencii Sportkinetics 91, Olomouc.

Horváth, R. et al. (2010). Diagnostika motorickej výkonnosti a genetických predpokladov pre šport (Diagnostics of physical performance and genetic prerequisites for sports). Prešovská univerzita v Prešove.

Jakovlev, N.N. (1974). Biochimija sporta (Biochemistry of sport). Moskva, FiS.

Janouch, V. (1983). Pohybové schopnosti a ich rozvoj (Movement abilities and their development). In: Didaktika telesnej výchovy. Bratislava, SPN, p. 93-104.

Javůrek, J. et al. (1986). Kompenzační cvičení v rámci regenerace sil mladých sportovců (Compensatory exercises in part of regeneration of young athletes). Praha, VMO ČÚV ČSTV.

Jirka, Z. (1984). Komplexní regenerace sportovců (Complex regeneration of sportmen). Praha, VMO ÚV ČSTV.

Jolly, S.W., Crowder, V.R. (1987). The Evergy Continuum and the Stages of Velocity in Sprinting. Track and Field Quarterly Review, winter, p. 2890.

Joseph, P.T. (1984). Relationship of Selected Anthropometric and Strenght Variables to Speed Performance. Thesis to M.P.E. Gwalior (India). Jiwaji University.

Kampmiller, T. (2.5.1983). Meranie času opornej, letovej fázy, frekvencie a dĺžky krokov v atletických šprintoch (Measurement of contact time, flight phase, frequency and length of steps in athletic sprints). Príspevok na seminári VÚTK UK, Bratislava.

Kampmiller, T. (1984). Diagnostika predpokladov mládeže pre atletický šprint (Diagnostics of youth prerequisites for athletic sprint). Výskumná správa. Bratislava, FTVŠ UK.

Kampmiller, T., Koštial, J. (1986). Štruktúra a rozvoj rýchlostných schopností v atletických šprintoch mládeže (Structure and development of speed skills in youth athletic sprints). Metodický dopis. Praha, ÚV ČSTV.

Kampmiller, T., Koštial, J. (1987). Behy na krátke vzdialenosti (Running short distances) p.94-138. In: Kuchen et al. (1987). Teória a didaktika atletiky. Bratislava. SPN. 384p. ISBN 067-188-87.

Kampmiller, T., Koštial, J., Sedláček, J. (3.3.1988). Spresnená metodika centrálneho výberu do SVŠ v šprintérskych a prekážkových disciplínach (The precise methodology of the central selection for the SVŠ in sprint and obstacle disciplines). Realizačný výstup, Praha, 12 p.

Kampmiller, T., Koštial, J., Sedláček, J. (1990) Diagnosis and Verification of Assumptions on Young Male Sprinters. Physical Education Review 13, 2 Autumn, p. 146-150.

Kampmiller, T. et al. (1991). Rozvoj špeciálnych schopností supramaximálnou rýchlosťou (Development of special abilities at supramaximal speed). In: Telesná výchova a šport, 1 - 2, p. 4-7.

Karlson, J. (1975). Das mensliche Leistungsvermögen in Abhängigkeit (Human performance in dependency). Medizin und Sport 15, 12, p. 357.

Kasa, J. (2000). Športová antropomotorika (Sports anthropomotorics). Bratislava, Slovenská vedecká spoločnosť pre telesnú výchovu a šport, p. 209. ISBN 80-968252-3-2.

Klissouras, V. (1973). Prediction of potential performance with special reference to heridtiy. J. Sports Med. Phys. Fit. 13, 2, p. 100-107.

Kodým, M. et al. (1978). Výběr sportovních talentů (Selection of sport talents). Praha, Olympia.

Komadel, Ľ. (1976). Lekárske kritériá pri výbere talentovanej mládeže pre šport (Medical criteria in the selection of talented youth for sports). Metodický list SÚV ČSZTV 14, Bratislava, Šport, p. 15-38.

Korhonen M., T., Mero A., Suominen H. (2003). Age-Related Differences in 100-m Sprint Performance in Male and Female Master Runners. Medicine & Science in Sports & Exercise. The American College of Sports Medicine DOI: 10.1249/01.MSS.0000079080.15333.CA. p. 1419-1428.

Koštial, J. (1976). Určujúce faktory výkonnosti v behu na 110 m prekážok z hľadiska motorických schopností a telesného rozvoja (Determinants of performance in the 110 m hurdles in terms of motor skills and physical development). Rigorózna práca. Bratislava, FTVŠ UK.

Koštial, J. (1984). Účinnosť tréningového zaťaženia na pohybové schopnosti a výkonnosť mládeže v atletike - na príklade prekážkového behu (Effectiveness of training load on movement skills and performance of youth in athletics – on the example of hurdling. Kandidátska dizertačná práca. Bratislava, FTVŠ UK.

Koštial, J., Kampmiller, T. (1984). Stanovenie metodiky výberu pre zaraďovanie šprintérov do útvarov talentovanej mládeže z motorického hľadiska (Determination of the selection methodology for the inclusion of sprinters in the units of talented youth from a motor point of view). Rezortná výskumná úloha MŠ VIII-01/02-01/20, Bratislava, FTVŠ UK.

Koštial, J., Kampmiller, T. (1985). Stanovenie výberových kritérií do stredísk vrcholového športu v atletickom šprinte (Determination of selection criteria for top sport centres in athletic sprinting). Teor. Praxe těl. Vých. 9, p. 542-549.

Koštial, J. et al. (1990). Účinnosť tréningového zaťaženia v príprave mladých atlétov – šprintérov ŠS (The effectiveness of the training load in the preparation of young athletes – sprinters of sport school). Atletika 42, Metodické listy p. 13-15.

Koštial, J. et al. (2018). Štruktúra pohybovej činnosti atletických skokanských disciplín (Structure of Movement Activity of Athletic Junping Disciplines). Elektronická vedecká monografia, 2. Vydanie, Bratislava. Slovenská vedecká spoločnosť pre telesnú výchovu a šport, 129p., ISBN 978-80-89075-66-9.

Koštial, J. (2019). Účinnosť tréningového zaťaženia na zmeny pohybovej a športovej výkonnosti mladých atlétov prekážkárov. (Effectiveness of training load on changes in movement and sports performance of young hurdlers). VERBUM, Ružomberok. 99p. ISBN 978-80-561-0663-1.

Kovář, R. (1974). Vliv dedičnosti a prostředí na úroveň pohybových projevů člověka (Influence of heredity and environment on the level of human movement). Teor. Praxe těl. Vých. 22, 1974, 8, p.472-475.

Kovář, R. (1981). Human Variation in Motor Abilities and its Genetic Analysis. Praha, Univerzita Karlova.

Kuchen, A. (1965). K otázkam pohybových vlastností a ich zisťovania (On questions of movement properties and their detection). Těl. Vých. Mlád. 31, 10.

Kuchen, A. et al. (1981). Východiská pre výber a rozvoj talentov v športe (Starting points for the selection and development of talents in sports). Zborník VMR SÚV.

Kuchen, A. et al. (1987). Teória a didaktika atletiky (Theory and didactics of athletics). Bratislava, SPN. 384p. ISBN 067-188-87.

Kunz, H., Kaufmann, D.A. (1981). Biomechanics of Hill Sprifing. Track Technique, 1981, Winter, p. 2603.

Kuznecov, V.V., Petrovskij, V.V., Šustin, N.V. (1979). Modeľnyje charakteristiki legkoatletov (Model characteristics of athletes). Kijev, Zdorovja.

Laczo, E. (1977). Štruktúra a možnosti predikcie športového výkonu v behu na 100 m prekážok z hľadiska pohybových schopností. (The structure and possibilities of predicting sports performance in the 100 m hurdles from the point of view of movement skills). Rigorózna práca. Bratislava, FTVŠ UK.

Laczo, E. (1983). Niektoré hľadiská výberu a športovej prípravy talentov v atletike (Some aspects of the selection and sports training of talents in athletics). In: Havlíček, I. et al.: K metódam skúmania v športe (To research methods in sports). VII. Zborník TŠ SÚV ČSZTV. Bratislava, Šport.

Laczo, E. (1987). Zvyšovanie športového výkonu v závislosti od rozvoja pohybových schopností a tréningového zaťaženia v prekážkovom šprinte. (Increasing sports performance depending on the development of movement skills and training load in hurdle sprint). Kandidátska dizertačná práca. Bratislava, FTVŠ UK.

Laczo, E. et al. (2014). Rozvoj a diagnostika pohybových schopností detí a mládeže (Development and diagnosis of movement abilities of children and youth). Bratislava: Moderné vzdelávanie pre vedomostnú spoločnosť, p. 154. ISBN 978-80-971466-0-3.

Lee, M. J. (1987). Psychological Readinis of Children for Competitive Sports. In: The growing Child in Competitive Sport. BANC International Congress Proceedings National Coaching Foundation, Leeds (Englands).

Letzelter, M. (1971). Zum Krafttraining der Sprinter (About strength training of sprinter), Leichtathletik, 43, p. 1531.

Letzelter, M. (1977). Hůrdensprint (Hurdling). Berlin, Můnchen, Frankfurt a M., Verlag Bertels und Wernitz KG.

Levčenko, A. et al. (1987). Na distanciji Benjamin Džonson (Benjamin Jonson on track). Leg. atl. 6, p. 20.

Loginov, A., Alabin, N., Juškevič, T. (1973). Sprint: Voprosy upravlenija (Sprint: questions of control). Leg. Atl. 9, p. 19.

Macák, I. (1982). Psychológia športu (Psychology of sport). Skriptá. Bratislava, FTVŠ UK.

Mall, N.N. (1982). Cardiovascular Responses of Active, Passive and Yogic Recovery Procedures and Maximum Work Output. Thesis for Ph.D., Chandigar (India). Panjab University.

Martín-Fuentes, I., Tillaar, R. (2022). Relationship between Step-by-Step Foot Kinematics and Sprint Performance. Int. J. Environ. Res. Public Health, 19, 6786. https://doi.org/10.3390/ijerph19116786

Matoušek, R. (1977). Limitující faktory výkonnosti v běhu na 400 m překážek mužů z hlediska bežecké výkonnosti a tělesného rozvoje (Limiting factors of men's 400 m hurdles performance in terms of running performance and physical development). ŠVOUČ. Bratislava. FTVŠ UK.

Matoušek, R. (1978). Změny faktorů- určujících sportovní výkon v běhu na 400 m překážek v jednotlivých věkových kategoriích (Changes in factors determining sports performance in the 400 m hurdles in individual age cathegories). Tréner 22, 8, metodické listy, p. 9-13.

Matoušek, R. (1980) Dynamika změn faktorů určující sportovní výkon v běhu na 400 m překážek (Dynamics of changes in factors determining sports performance in the 400 m hurdles). Diplomová práca. Bratislava, FTVŠ UK.

Matoušek, R. (1986). Zpravodaj realizačního týmu 400 m překážek mužů (Newsletter of the implementation team of the men's 400 m hurdles) 4/86. Strojopis.

Matoušek, R. (1988). Účinnosť tréningového zaťaženia v etapách dlhodobej športovej prípravy v prekážkových behoch (The effectiveness of the training load in the stages of long-term sports training in hurdle courses). KDP, Bratislava, FTVŠ UK.

Matoušek, R., Sedláček, J. (1988). Rozvoj špeciálnych schopností v etape základnej a špecializovanej prípravy – 400 m prekážok (Development of special skills in the stage of basic and specialized training - 400 m hurdles). In: štruktúra športového výkonu, výber mládeže a rozvoj špeciálnych schopností v prekážkových behoch. Bratislava, MO SÚV ČSZTV, p. 54-69.

Matvejev, L.P. (1977). Osnovy sportivnoj trenirovki (Basics of sports training). Moskva, FiS.

Matvejev, L.P. (1982). Základy športového tréningu (Basics of sports training). Bratislava, Šport, 303 p.

Mero, A., Komi, V.P. (1990). Auswirkungenstimukierter supramaximaler Sprints auf die neuromusculare und anaerobe Leistung (Effects of stimulated supramaximal sprinting on neuromuscular and anaerobic performance). Leistungssport, 1 , p. 33-35.

Mero, A., Komi, P.V., Gregor, R.J. (1992). Biomechanics of Sprint Running, a Review. Sports Medicine 13 (6): p. 376-392.

Měkota, K. (1982). Koordinační schopnosti a pohybové dovednosti (Coordination skills and movement skills). Metodický dopis ÚV ČSTV. Praha, ÚV ČSTV.

Měkota, K., Blahuš, P. (1983). Motorické testy v tělesné výchově. (Motor tests in physical education). Praha, SPN. 336p.

Měkota, K. (2000). Definice a struktura pohybových schopností (Definition and structure of movement skills). In: Česká kinantropologie 2000, 1, p. 59-69.

Měkota, K., Cuberek, R. (2007). Pohybové dovednosti, činnosti, výkony (Movement skills, activities, performances). UP Olomouc. 164p. ISBN 978-80-244-1728-8.

Moravec, P. et al. (1984). Běh na 400 m mužů a žen. (400 m run for men and women). VMO ÚV ČSTV. Praha, Sportpropag.

Moravec, R., Šelingerová, M. (1987). Výber, prognóza športovej úspešnosti a príprava v skokoch (Selection, prediction of sports success and preparation in jumping). Metodický dopis. Praha, ÚV ČSTV.

Moravec, R. (1990). Telesný, funkčný rozvoj a pohybová výkonnosť 7-18 – ročnej mládeže v ČSFR (Physical, functional development and movement performance of 7-18-year-old youth in Czechoslovakia). Bratislava, Slovšport. 284p. ISBN 80-967487-1-8.

Moravec, R., Sedláček, J. (15.8.1991). Physical Fitness of Czechoslovak Childern and Youth (Age 7-18). Referát na 34. svetovej konferencii ICHPER, Limerick (Írsko), 8 p.

Moravec, R., Kampmiller, T., Vanderka, M., Laczo, E. (2004). Teória a didaktika športu (Theory and didaktics of sport). FTVŠ UK Bratislava & Slovenská vedecká spoločnosť pre telesnú výchovu a šport. 212p. ISBN 80-89075-22-3.

Moser, H. (1960). ÜBer die Vererbung der sportlichen Fähigkeiten (About the inheritance of athletic ability). München.

Neumann, J. (2003). Cvičení a testy obratnosti, vytrvalosti a síly (Exercises and tests of dexterity, endurance and strength). Praha. Portál. 157 p. ISBN 80-7178-730-2.

Novák, M. (1982). Zpravodaj realizačního týmu 400 m překážek (Newsletter of the implementation team of 400 m hurdles) 4/82. Strojopis.

Novák, M. (1983). Zpravodaj realizačního týmu 400 m překážek (Newsletter of the implementation team of 400 m hurdles) 5/83. Strojopis.

Orlick, T. (1980). In Pursuit of Excellence. Ottava. Coaching Association of Canada and Terry Orlick.

Oros, F. (1989). Boj o stotiny (Fight for hundredths). In: Atletika 41, 5, p. 13-20.

O´Sullivan, J. (2013). Our biggest mistake: talent selection instead of talent identification. Changing thegame project. Retrived from: https://changingthegameproject.com/our-biggest-mistake-talent-selection-instead-of-talent-identification.

Ozolin, N.G. (1970). Sovremennaja sistema sportivnoj trenirovki (Present sytem of sport training). Moskva, FiS.

Ozolin, N.G. - Voronkin V.I. (1979). Legkaja atletika (Athletics). 3. vyd. Moskva, FiS.

Pávek, F. (1977). Tělesná výkonnost 7-19 leté mládeže ČSSR (Physical performance of 7-19-year-old youth of the Czechoslovak Republic). Praha, Olympia.

Perič, T. (2010). Identifikace sportovních talentů (Identification of sport talents). Praha, Grada Publishing.

Perič, T., Ružbarský, P. (2018). Talent Selection and the Present? The Way Sports Precontions are determined in Slovakia. Gymnasium. Scientific Journal oof Education, Sports and Health. Vol. 19, 1, p. 52-62. ISSN 2344-5645.

Platonov, V.N. (1980). Sovremennaja sportivnaja trenirovka (Present sport training). Kijev, Zdorovja.

Popov, V.B., Suslov, F.P., Livado, E.I. (1984). Junyj legkoatlet (Young athlet). Moskva, FiS.

Prakash, O. (1986). A Comperative Study of Personality Traits of Athletes Participaling in Track Events and Field Events. Thesis to M.P.E., Gwalior (India), Jiwaji University.

Puzio, W. (1974). Gibkosc v treningu plotkarzy (Flexibility in hurdler training). Lek. Atlet. 19, 6, p. II-III.

Rankinen, T., Bouchard, C. (2011). Genetic Predictors of Exercise Training Response.Current Cardiovascular Risk eports, 5(4), p. 368-372. Avaulable at: http://link.springer.com/10.1007/s12170-011-0179-z.

Razumovskij, J.A. (1983). Štruktúra telesnej pripravenosti atlétov (Structure of athletes physical preparation) . Tréner 27, 11, p. 487-490.

Reisenauer, R. (1970). Metody matematické statistiky a jejich aplikace. Praha, SNTL.

Riordan, J.W. (1988). Soviet Sport and Perestroika. In: Physical Education and Sport Under Communism. University of Manchester, England, December, p.31.

Robinson, F.C. et al. (1974). Modern Techniques of Track and Field. Utah, Philadelphia, Brigham Young University Provo.

Roth, S.M. (2012) Critical overview of applications of genetic testing in sport talent identification. Recent Pat DNA Gene Seq., 6(3), p. 247-255.

Ružbarský, P. (2018). Antropomotorika pre študijné programy telesná výchova, trénerstvo a šport pre zdravie. (Anthropomotorics for physical education, coaching and sport for health study programs. UK PU Prešov, 79p. ISBN 978-80-555-2042-1.

Ružbarský, P., Perič, T. (2021). Výsledky prvého celoštátneho testovania pohybových predpokladov detí mladšieho školského veku – žiakov 1. ročníkov základných škôl (The results of the first nationwide testing of the movement abilities of children of younger school age - pupils of the 1st grade of elementary schools). Prešovská univerzita v Prešove. 190 p. ISBN 978-80-555-2391-0.

Růžičková, M. (1986). Využití motorických testů pro predikci výkonnosti ve sportovní gymnastice u 4-6 letých dívek (Use of motor tests to predict performance in sports gymnastics in 4-6year old girls). Kand. Dizertácia. Bratislava, FTVŠ UK.

Řeháková, S. (1982). Faktory limitující výkonnost v běhu na 400 m překážek žen (Factors limiting performance in women's 400 m hurdles. Diplomová práca. Bratislava, FTVŠ UK.

Řehoř, E. (1975). Analýza niektorých rodinných znakov čs. olympionikov (Analysis of some family characters of Czechoslovak participants in the Olympic Games). Acta fac. educ. Phys. UC XV. Bratislava, SPN, p. 141-160.

Sadovskij, V.V. (1970). Barjernyj beg (Hurdling). Moskva, FiS.

Schnabel, G., Harre, D., Borde, A. (1994). Trainingswissenschaft. Leistung – Training – Wettkampf (Training science. Performance – Training – Competition). Berlin, Sportverlag.

Sedláček, J. (1979). Podiel úrovne silovej pripravenosti a ohybnosti na športovej výkonnosti v behu na 400 m prekážok (The share of the level of strength preparation and flexibility on sports performance in the 400 m hurdles race). Diplomová práca. Bratislava, FTVŠ UK.

Sedláček, J. (1983). Závislosť výkonnosti v běhu na 400 m překážek od úrovně síly a ohybnosti (Dependence of performance in the 400 m obstacle course on the level of strength and flexibility). Tréner, 7, p.304-305.

Sedláček, J. (1986). Změny rychlosti a rytmu běhu na 400 m překážek mužů (Changes in speed and rhythm of men's 400 m hurdles). In: Tréner 10, p. 446-451.

Sedláček, J. (1987). Vliv posilování na rozvoj rychlostních schopností (The influence of strengthening on the development of speed abilities). Atletika 39, 3, metodické listy p. 13-14.

Sedláček, J. (1988). Efektívnosť centrálneho výberového konania v atletických šprintoch so zameraním na motorické faktory (Effectiveness of the central selection procedure in athletic sprints with a focus on motor factors). Predvýskum Kandidátskej dizertačnej práce. Bratislava, FTVŠ UK.

Sedláček, J. (1989). Efektívnosť centrálneho výberového konania v atletických šprintoch (The effectiveness of the central selection procedure in athletic sprints). In: Teor. Praxe těl. Vých. 37, 4, p. 212-225.

Sedláček, J. (1991). Diagnostika trénovanosti (Diagnosis of training). In: Atletika (zvolený šport). Bratislava, UK.

Sedlacek, J., Matousek, R., Holcek, R., Moravec, R. (1994). The Influence of the Political Changes on the High Performance Sport Organization in Czechoslovakia: 341-347. In: Wilcox, R. C. (1994). Sport in the Global Village. Fitness Information Technology, Inc. Morgantown: 521p. ISBN 0-9627926-4-0.

Sedláček, J. (1994). Predikčná validita výberových kritérií v behoch na krátke vzdialenosti. (Predictive validity of selection criteria in short distance running). Acta Fac. Educ. Phys. Univ. Comenianae, XXXV. p. 56-87.

Sedláček, J., Cihová, I. (2009). Športová metrológia. Bratislava, ICM Agency, 124p. ISBN 978-80-89257-15-7.

Seliger, V. (1967). Energetický metabolizmus u vybraných tělesných cvičení (Energy metabolism in selected physical exercises). Praha., Olympia.

Seliger, V., Trefný, Z. (1967). Základy fyziologie tělesných cvičení (Basics of the physiology of physical exercises). Praha, SZN.

Seliger, V., Přibylová, A. (1972). Energetický výdej u lehkoatletických výkonů (Energy expenditure in athletic performances). In: Ľahká atletika z lekárskeho aspektu. Metodický list ÚV STO. Bratislava, p. 14-17.

Sermejev, B.V. (1970). Sportsmenam o vospitanii gibkosti (Flexibility education of sportmen). Moskva, FiS.

Serresse, M. et al. (1988). Estimation of the Contribution of the Various Energy Systems during Maximal Work of Short Duration. International Journal of Sports Medicine, 9, p. 456-460.

Siris, P.E. (1974). Otbor detej i prognozirovanije ich sposobnostej po legkoj atletike (The selection of children and the prediction of their athletic ability). Zborník pedagogika – psychologija. Moskva.

Siris, P.E., Gajdarska, P.M., Račev, K.I. (1983). Otbor i prognozirovanije sposobnostnej v legkoj atletike (Selection and prediction of abilities in athletics). Moskva, FiS.

Slamka, M. (1981). Meranie rýchlosti, vzdialenosti, dĺžky kroku a doby opornej fázy pri behoch a skokoch (Measurement of speed, distance, stride length and support phase time during running and jumping). Teor. Praxe těl. Vých. 29, 6, p. 278-282.

Smirnov, J.I., Ivanov, V.V., Fedjajev, J.A. (1978). Metrologičeskaja- ocenka izmerenij vremennych parametrov begovogo šaga (Metrological evaluation of time changes of running step parameters). Teor. Prakt. Fiz. Kuľt. 11, p. 9-13.

Sodhi, H.S., Sidhu, L.S. (1984). Physique and Selection of Sportsman. Patiala (India). Panjab Publiching House.

Spiriev, B., Kovács, G. (1987). Scoring Table for Track and Field Road and Walking Events. Buapest, Hungarian Athletic Association.

Sprague, P., Mann, R.V. (1982). The Effects on Muscular Fatique on the Kinetics of Sprint Running. Research Quarterly for Exercise and Sport, 53, 1, p. 60-66.

Strokina, A.N. (1965). Nekotory morfologičeskije osobennosti sportsmenov, zanimajuščichsja legkoj atletikoj i plavaniem (Some morphological peculiarities of sportsmen who are interested in athletics and swimming). Avtoreferat KDP. Moskva, GCOLIFK.

Susanne, C. (1971). Hérédité des caractéres anthropologiques mesurables (Inheritance of measurable anthropological traits). Bull, Mém. Soc. Anthrop. Paris. 7, p. 169.

Susanne, C. (1977). Individual Age Changes of the Morphological Charakteristics. J. hum. Evol. 6, p. 131-189.

Sutcliffe, P. (1988). The German Democrafic Repoublic. An Overview. In: Physical Education and Sport Under Communism. University of Manchester, p. 3.

Sýkora, F. (1972). Somatický vývoj a pohybová výkonnosť bratislavskej mládeže (Somatic development and movement performance of Bratislava youth). Bratislava, ES UK.

Šaffa, J. (1977). Sledovanie vzťahov medzi frekvenciou a dĺžkou kroku u šprintérov rozličnej výkonnosti (Tracking the relationship between step frequency and length in sprinters of different performance). Diplomová práca. Bratislava, FTVŠ UK.

Šelingerová, M., Kampmiller, T., Koštial, J. (1988). Závislosť športového výkonu a motorickej výkonnosti šprintérov na telesnom rozvoji (Dependence of sports performance and motor performance of sprinters on physical development). In: Sborník referátü z celostátní konference Tělesná kultúra v životě mladé generace. II. diel. Praha, VMO ÚV ČSTV, p. 163-171.

Šimková, N., Ramacsay, L. (1983). Výška tela ako kritérium pri výbere športovo talentovanej mládeže (Body height as a criterion in the selection of athletically talented youth). Tréner 27, 10, p. 468-471.

Šimková, N. (1987). Genetická podmienenosť faktorov športovej činnosti (Genetic conditionality of sports activity factors). In: Športová príprava talentovanej mládeže. VMR SÚV ČSZTV. Zborník XIII. Bratislava, Šport, p. 14-35.

Šimonek Sr, J. (1971). Rozvíjanie sily (Strength developement). In: Športová príprava mládeže. Metodický list ÚV STO. Bratislava, p. 54-60.

Šimonek Sr, J. (1980). Ohybnosť - kĺbová pohyblivosť (Flexibility - joint mobility). In: Telesná príprava športovcov. Rozvoj pohybových schopností. Bratislava, Šport, p. 118-128.

Šimonek Sr, J. et al. (1985). Koordinačné schopnosti (Coordination skills). Metodický list SÚV ČSZTV. Bratislava, SÚV ČSZTV.

Šimonek Sr, J. (1990). Prostriedky a metódy rozvoja koordinačných schopností (Means and methods of development of coordination abilities). In: Atletika (špecializácia). Bratislava, UK, p. 50-54.

Šimonek Jr, J. et al. (2008). Normy koordinačných schopností pre 11-15 ročných športovcov (Standards of coordination skills for 11-15year old athletes). PF UKF Nitra. 107 p. ISBN 978-80-8094-297-7.

Šimonek Jr, J., Židek, R. (2019). Talent v športe (vyhľadávanie, identifikácia, rozvoj). (Talent in sports (search, identification, development)). PF UKF Nitra, SPU. 104p. ISBN 978-80-558-1413-1.

Špokas, A.A., Filin, V.P., Jankauskas, J.M. (1977). Nekotorijie voprosy otbora i prognorizovanija sposobmnostnej junych sportsmenov (Some requests from the selection and prognostication of the potential of young sportsmen). Teor. Prakt. Fiz. Kuľt.č. 3, s. 40-43.

Štěpánek, J., Moravec, P. (1990). Časová analýza, frekvence a délka kroku v běhu na 100 m na OH 88 (Time analysis, frequency and stride length in the 100 m run at the 88th Olympics). In: Atletika 42, 5, p. 13-21.

Štěpnička, J. (1968). Problém typologie tělovýchovného pohybu (The problem of the typology of physical education movement). In: Acta Univ. Carol. Gymn. Praha, 1, p. 23-28.

Štěpnička, J. (1972). Typologická a motorická charakteristika sportovcü a studentü vysokých škol (Typological and motor characteristics of athletes and university students). Praha, Univerzita Karlova.

Štulrajter, V. (1984). Strečing. Cvičenia kĺbovej pohyblivosti (Stretching. Exercises of joint flexibility). Bratislava, VMO ČSZTV.

Šuvalov, G., Borzov, V., Ljuľko, R. (1980). Mužskij sprint: problemy i perspektivy (Men's sprint: problems and perspectives). Leg. Atl. 5, p. 11.

Tabačnik, B. (1979). Kak naiti sprintera (How to find a sprinter)? Leg. Atl. 3, p. 12-14.

Tanner, J.M. (1964). The Physique of the Olympic Athlete. London, George Allen and Unwin. LTD.

Ter-Ovanesjan, A.A. (1978). Pedagogičeskije osnovy fizičeskogo vospitanija (pedagogical foundations of physical education). Moskva. FiS.

Thies, G., Schnabel, G., Baumann, R. (1980). Training von A bis Z. Kleines Wörterbuch für Theorie und Praxis der sportlichen Trainings. (Training from A to Z. Small dictionary for theory and practice of athletic training). Berlin, Sportverlag.

Tkáč, M. (1989). Stanovenie anaeróbnych schopností testom opakovaných výskokov (Determining anaerobic abilities by the test of repeated jumps). Teor. Praxe těl. Vých. 37, 10, p. 606-616.

Tolstopjatov, N. (1975). Zaboty barjeristov (Care of hurdlers). Leg. Atlet. 9, p. 27.

Tošnar, M. et al. (1962). Překážkové běhy (Hurdling). Praha, STN:

Ťjupa, V.V. et al. (1978). O mechanizme vzajimodejstvija sprintera s oporoj (About the mechanism of interaction of a sprinter with a contact of a mat). Teor. Prakt. Fiz. Kuľt. 9, p. 9-13.

Vacula, J. a kol. (1975). Trénink atletických disciplín (Training of athletic disciplines). Praha, SPN.

Vajcechovskij, S.M. (1975). Kniha trénera (Coach's book). Praha, Olympia.

Vanderka, M., Kampmiller, T. (2013). Kinematics of Sprinting in Children and Youths. New Studies in Athletics · no. 1-2, p. 35 – 45.

Van Praagh et al. (1991). Oxygen uptake during a 30 s supramaximal exercise in 7 to 15 years old boys. In: Children and Exercise Pediatric Work Physiology XV. Budapest, Alföldi Nyomba.

Vojtašák, J. (1989). Kde sú hranice fyziologického zaťaženia chrbtice u mladých atlétov (Where are the limits of the physiological load on the spine in young athletes)? Atletika XLI, 8. Metodické listy, p. 19-20.

Wendland, U. (1984). Talentauswahl mit Hilfe der Wissenschaft? Strategien und ihre mögliche Folgen (Talent selection with the help of science? Strategies and their possible consequences). Leistungssport 14, 2, p. 14-20.

Winer, B.J. (1962). Statistical Principles in Experimental Design. New York. Mc Craw – Hiil Book Company.

Wright, B. (1974). Testy gibkosci dla plotkarzy (Flexibility tests for hurdlers). Lek. Atlet. 1974, p. 6-7.

Zaciorskij, V.M. (1974). Kibernetika, matematika, sport (Cybernetics, mathematics, sports). Preklad, 1. vyd. Praha.

Zaciorskij, V.M. (1970). Tělesné vlastnosti sportovce (Physical characteristics of an athlete). Praha, KU.

Zaciorskij, V.M. (1974). Kibernetika, matematika, sport (Cybernetics, mathematics, sports). Preklad, 1. vyd. Praha.

Zimkin, N.V. (1956). Fiziologičeskaja charakteristika sily, bystroty a vynoslivosti (physiological characteristics of strength, speed and endurance). Moskva, FiS.

Zimkin, N.V. (1975). Fiziologia čeloveka (Human physiology). Moskva, FiS.

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About author

Jaromír Sedláček (*1955) – completed his university studies in Bratislava at the Faculty of Physical Education and Sports, Comenius University, teaching in Physical Education and Mathematics (1974 – 79). He worked at Dukla Prague as a sports instructor (1979-80), at the Elementary School in Slavkov near Brno as a teacher (1980-81), at the Center for Top-level Sports as a coach (1981-82), at the Faculty of Physical Education and Sports of the Comenius University in Bratislava as a senior assistant, reader and professor (1982-2020), since 2011 he has been working as a professor at the Faculty of Education of the Catholic University in Ruzomberok, in 2011-14 he was the head of the international research team at the Faculty of Sports Studies of Masaryk University in Brno, since 2016 he has been working as a professor at the Faculty of Sports of Prešov University in Prešov.

During his working career, he received the titles of Doctor of Education (PaedDr., 1986), Candidate of Pedagogical Sciences (CSc., resp. PhD., 1992), the titles of readership (1999) and professorship (2011) in the field of Sports Kinanthropology. He also holds the highest coaching qualification in athletics, specializing in sprints and hurdling.

He was actively involved in many sports, for example in football, netball, table tennis and athletics. He achieved the highest level of performance in athletics, in the 400 m hurdles (personal record is 52.31s); he is a multiple Slovak champion and medalist in the 400 m hurdles and a medalist in relay races from the championships of Czechoslovakia and Slovakia. He is still actively playing table tennis (2nd - 4th Slovak league and veteran European and world championships).

In his scientific and research activities he completed more than 15 research papers and grants in the following areas: selection, prediction of performance and training of youth in performance and elite sports; physical fitness and movement performance of children, youth and adults; entrance exams for faculties with a focus on physical education; biomechanical analysis of movement activity; fitness training in several sports.

He carried out his teaching and pedagogical activities at the following universities: Comenius University in Bratislava, Catholic University in Ružomberok, Masaryk University in Brno and University of Prešov in Prešov. He led and leads exercises, seminars and lectures at bachelor's, master's and doctoral degrees. Specific subjects include Athletics, Athletics Specialization, Sports Metrology, Didactic of Education, Scientific Research Methodology, Pedagogical Practice, etc. He guaranteed and guarantees study programs (Comenius

University, Prešov University). He is the chairman of the Sports Educology Committee at the Faculty of Sports of the University of Prešov. He was and is the supervisor of approximately 50 final theses (bachelor's and master's). He was also the supervisor of seven completed dissertation theses (Comenius University and Prešov University), of which one dissertation was from abroad.

He also represented Slovakia in several international organizations (EUPEA, FIEPS) and also held the position of secretary in the European section of FIEP (2007 – 2013). He was and is a member of several faculty and university scientific councils (Faculty of Physical Culture at Palacký University in Olomouc, Faculty of Physical Education and Sports Comenius University in Bratislava, Faculty of Sports of Prešov University and Prešov University in Prešov). He was a member of several domestic and foreign editorial boards of professional journals. His assessment and review activities are extensive as well.

He received several awards for his activities, the most important of which are: Praising letter of the Sport Department of European Council /1997/ and Award in competition of „scientific contribution of year2000“held by European Athletic Association.

He has published more than 250 contributions in domestic and, to a large extent, in foreign professional and scientific journals and publishing units. He registers more than 800 citations to his publications and research work.