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# KINEMATIC PARAMETERS OF THE RUNNING STRIDE IN 7- TO 18-YEAR-OLD YOUTH

# KINEMATIČNI PARAMETRI TEKAŠKEGA KORAKA PRI MLADIH, STARIH OD 7 DO 18 LET

## ABSTRACT

The authors deal with a cross-sectional analysis of the ontogenetic characteristics of basic kinematic parameters of the running stride in terms of age and gender of youth aged 7 to 18 years. The following were monitored: average velocity, stride frequency and length, duration of support and flying phase, as well as other derived indicators at 10 metre with a 15 metre flying start. The sample consisted of 1,299 male and 1,288 female students of elementary and high schools in Bratislava. The authors determined the high dependency of running speed and stride length on age. In contrast, there was high ontogenetic stability of some indicators (stride frequency, duration of support and flying phase) in the population of 7- to 18-year-old youth. Ontogenetically stable parameters deteriorated partially in the prepubescent and beginning of the pubescent period at ages 11 to 15. This relates to the rapid growth of body height and weight and the deterioration of biomechanical and coordination conditions of the organism. These findings led the authors to the conclusion that ontogenetically stable indicators comprise so-called dispositional factors in evaluating the level of talent for running speed.

*Key words:* running, kinematics parameters, maximal speed, ontogenesis

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## IZVLEČEK

Avtorji raziskave so opravili presečno analizo ontogenetskih značilnosti osnovnih kinematičnih parametrov tekaškega koraka glede na starost in spol pri mladih v starosti 7 do 18 let. Spremljali so: povprečno hitrost, frekvenco in dolžino koraka, trajanje faze podpore in lebdenja ter druge izpeljane kazalce pri teku na 10 m s 15-metrskim letečim startom. Vzorec je zajemal 1299 učencev oz. dijakov in 1288 učenk oz. dijakinj iz osnovnih in srednjih šol v Bratislavi. Avtorji so ugotovili, da sta hitrost teka in dolžina tekaškega koraka močno odvisna od starosti. Po drugi strani pa so opazili visoko ontogenetsko stabilnost kazalcev (frekvenca koraka, trajanje faze podpore in lebdenja) pri populaciji mladih, starih od 7 do 18 let. Ontogenetsko stabilni parametri so se nekoliko poslabšali v obdobju pred puberteto in na začetku pubertete pri starosti 11 do 15 let. To je povezano s hitro rastjo telesne višine in teže ter s poslabšanjem biomehaničnih in koordinacijskih pogojev organizma. Na podlagi teh ugotovitev so avtorji sklepali, da ontogenetsko stabilni kazalci za ocenjevanje nadarjenosti za tekaško hitrost vključujejo tako imenovane dispozicijske dejavnike.

*Ključne besede:* tek, kinematični parametri, maksimalna hitrost, ontogeneza

# INTRODUCTION

Running speed is one of those human motor capabilities that are difficult to develop. They are substantially conditioned by hereditary factors on the CNS level, the structure of muscle fibres, energy systems and it is hard to influence them through sports training. Besides, running speed is a basic motor capability and is part of the structure of sport performance in many sports events. These are the reasons underlining the particular importance of the early recognition of a talent to run quickly and recognising the kinematic parameters that influence it. That is why it is necessary to search for such parameters of running speed (predictors) which are relatively independent of age and demonstrate high ontogenetic stability.

In the phase of maximum speed both the frequency and length of the stride are relatively constant, while the proportion between the contact and flight phases of a sprinter's stride is also stabilised. The zone in which sprinters achieve their absolute maximum speed is very limited. In principle, the best sprinters can sustain this phase for 10 to 20 metres. The zone of maximal speed is located somewhere between 60 and 80 metres among men and between 50 and 70 metres among women. Maximal speed is always a product of optimal stride length and frequency. There are no differences in the length of stride between elite and sub-elite sprinters, with differences only existing in the frequency of the stride (Donati, 1996; Mackala, 2007; Seagrave, Mouchbahani, & O`Donnel, 2009).

Studies of the kinematics of sprinting usually focus on top- or high-level athletes where they find the most important parameters. The most important generator of sprinting stride efficiency is the execution of the contact phase, especially the ratio between the braking phase and propulsion part (Čoh, Škof, Kugovnik, & Dolenec, 1994; Alcaraz, Palao, Elvira, & Linthorne, 2008). To ensure the maximum sprinting velocity, the force impulse must be as small as possible in the braking phase, which is enabled through an economic placement of the foot of the push-off leg as closely as possible to the vertical projection of the body's centre of gravity on the surface.

It seems that the basic kinematic characteristics of running during the phase of maximum speed are: momentary and average velocity, frequency and length of the running stride, duration of the support phase and the flying phase and efficiency index, which is defined by the duration of the support phase and the running phase ratio. The duration of the support phase in 13- to 16-year-old youth presents a stable factor in terms of ontogenesis (Tabačnik, 1979; Siris, Gajdarska, & Račev, 1983). The period of the so-called "sensitive phase" in the development of children (9-13 years), which is very suitable for the development of speed potential. The central nervous system is being developed where the formation of the myelin nerve sheath is particularly emphasised as it serves as a transporter of neural impulses from the central nervous system to active muscles. In this period, particularly the speed of the transfer of such impulses, which generate the speed of movement, can be influenced.

The level of stride frequency during the phase of maximum speed is a stable factor in human ontogenesis and can only be influenced by appropriately oriented, specialised sport preparation (Korneljuk & Marakušin, 1977). The linear independence of the velocity of running and the support phase duration has also been found (Bogdanov, 1974; Tjupa et al., 1978; Kampmiller & Koštial, 1986). This finding shows that it is a substantial criterion for determining the maximal running speed of humans.

To determine basic kinematic parameters of the running stride over a distance (10m) with a 15 metre approach (flying start) in cross-sectional age, we used samples of male and female students of elementary and high schools in Bratislava (ISCED 2, 3) aged 7 to 18 years. The sample was also used to point out the ontogenetic stability of the frequency and length of the running stride, duration of the support phase and the flying phase, as well as to determine basic measures of location (mean) and of variability (standard deviation) in one-year intervals.

## METHODS

The samples consisted of 7- to 18-year-old students of elementary and high schools in Bratislava. There were 1,299 boys and 1,288 girls in the samples. The subjects were supposed to run at maximum speed over a 25-metre track. The velocity over the 10-metre distance after a 15-metre flying start was recorded by timing gates in standard conditions (gymnasium, sports hall). The run was carried out on a contact platform in combination with a "Lokomometer" measuring device which uses computer technology to evaluate basic kinematic parameters of the running step (velocity of the 10-metre distance, frequency and length of the running stride, duration of the support phase and the flying phase and efficiency index, which is defined by the duration of the support phase and the running phase ratio). The contact platform was 17 metres long and consisted of two conductive layers separated by non-conductive elastic grading. During the contact of the foot with the surface, the contact platform worked as an electric circuit switch so that, during the flight phase, the circuit was disconnected. Length parameters were measured by the "Lokomometer" (Šelinger & Kampmiller, 1994). The time variables were measured with 0.001 s accuracy and the length variables with ± 0.005 m. Body height was determined with ± 0.005 m accuracy and body weight with ± 0.5 kg. Age was determined with an accuracy of 0.1 years.

We used no research procedure that could harm the child either physically or psychologically, we took special effort to also explain the research procedures to the parents and were especially sensitive to any indicators of discomfort. This was because with the child and parents or guardians informed consent requires that people interacting with the child during the study be informed of all features of the research which may affect their willingness to participate.

The samples were divided into groups according to age with a one-year gap between the groups, on average from 6.5 to 17.5 years old. Means and standard deviations were calculated. Ontogenetic tendencies were represented graphically and, by means of the significance of difference, by a two-sample statistical t-test of middle values of interannual increase. Statistical significance was evaluated on the 1% and 5% levels. In addition, a correlation analysis in the IBM SSP program was undertaken.

## RESULTS

Tables 1 and 2 present the basic statistical characteristics of the observed parameters Figure1 shows the course of the average running speed, which shows parallel and linear growth from 6.5 to 13.5 years of age in both boys and girls. Later on the speed among the boys increases steeply, while it stagnates among the girls. A similar trend is revealed in Figure2 (average stride length). The stride frequency (Figure3) shows a very stable tendency with a slight decrease at the end of the observed period. This parameter changes significantly only during the prepubescent and beginning of the pubescent period (from 10.5 to 14.5 years of age).

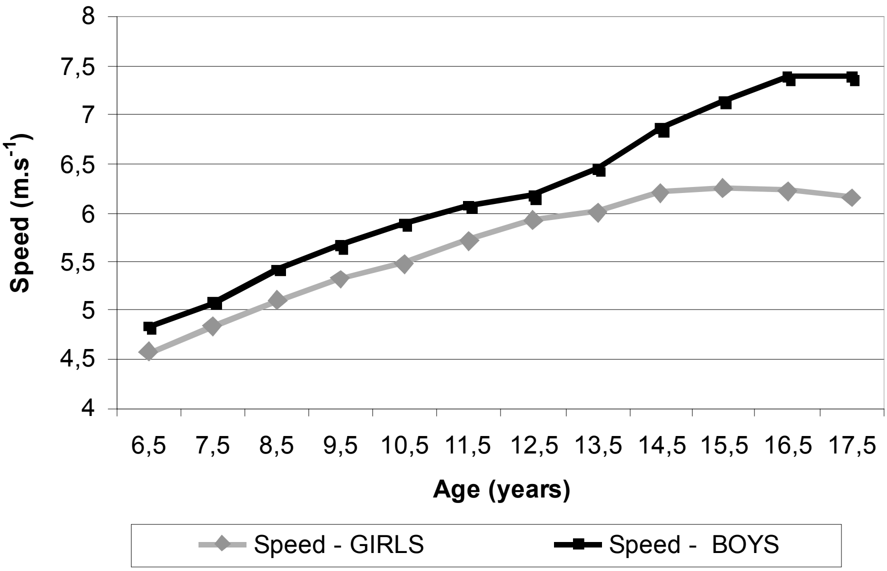


Figure 1: Average running speed over the 10-metre distance after a 15-metre flying start


Figure 2: Average stride length over the 10-metre distance after a 15-metre flying start

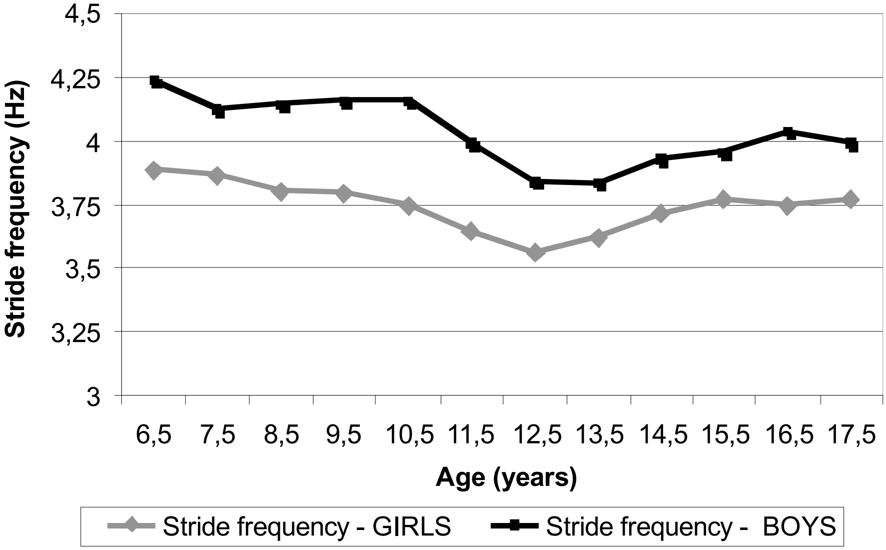


Figure 3: Average stride frequency over the 10-metre distance after a 15-metre flying start

The duration of the contact of the foot with the surface (Figure 4) displays a similarly stable course as the stride frequency. As a result of biological changes, the duration of the contact lengthens between 10.5 and 13.5 years of age and gradually returns to seen at 7 years of age. This parameter of the kinematic structure of the running step also displays a high level of ontogenetic stability, as proven by the interannual t-test values in Tables 1 and 2.

Table 1: Statistical characteristics of age, somatic and kinematic parameters of the running stride over a 10-metre distance after a 15-metre flying start – BOYS and significance of difference between the variables

| Group | Statistic | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | speed | Relative speed | Relative stride length | tf/tc | Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Mean | 6.50 | 122.45 | 22.79 | 149.10 | 89.35 | 114.80 | 4.24 | 4.82 | 2.15 | .94 | 0.60 | Mean |
| n | Stdev | 0.20 | 4.21 | 2.86 | 13.55 | 14.67 | 11.81 | .33 | .40 | .30 | .09 | .11 | Stdev |
| 29 | t (1-2) | -13.59 | -4.34 | -2.59 | -.60 | -1.35 | -4.02 | 1.60 | -2.80 | 1.05 | -2.16 | -.98 | t (1-2) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.548** | **NS 0.179** | **0.00** | **NS 0.111** | **0.00** | **NS 0.297** | **0.03** | **NS 0.329** | **Sig** |
| **2** | Mean | 7.50 | 127.73 | 25.13 | 151.00 | 94.12 | 123.99 | 4.12 | 5.08 | 2.08 | .97 | 0.63 | Mean |
| n | Stdev | 0.39 | 6.26 | 4.68 | 15.75 | 17.78 | 11.04 | .35 | .45 | .34 | .07 | .14 | Stdev |
| 137 | t (2-3) | -25.28 | -7.75 | -5.22 | 1.44 | -.76 | -5.44 | -.39 | -6.02 | 2.49 | -1.38 | -1.30 | t (2-3) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.150** | **NS 0.449** | **0.00** | **NS 0.695** | **0.00** | **0.01** | **NS 0.169** | **NS 0.21** | **Sig** |
| **3** | Mean | 8.50 | 134.07 | 28.68 | 148.13 | 95.67 | 131.88 | 4.14 | 5.43 | 1.96 | .98 | 0.65 | Mean |
| n | Stdev | 0.21 | 6.79 | 6.15 | 15.82 | 14.54 | 12.10 | .34 | .47 | .38 | .08 | 1.36 | Stdev |
| 118 | t (3-4) | -25.00 | -5.39 | -3.23 | .68 | -.38 | -3.80 | -.29 | -4.13 | 1.78 | -.94 | -.68 | t (3-4) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.497** | **NS 0.707** | **0.00** | **NS 0.73** | **0.00** | **NS 0.077** | **NS 0.348** | **NS 0.499** | **Sig** |

| Group | Statistic | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | speed | Relative speed | Relative stride length | tf/tc | Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **4** | Mean | 9.50 | 138.17 | 31.36 | 146.83 | 96.34 | 137.01 | 4.15 | 5.66 | 1.88 | .99 | 0.66 | Mean |
| n | Stdev | 0.40 | 6.06 | 7.44 | 16.15 | 14.85 | 10.69 | .34 | .47 | .38 | .07 | .13 | Stdev |
| 171 | t (4-5) | -22.95 | -5.56 | -2.71 | .72 | -.45 | -4.18 | -.03 | -4.07 | 1.17 | -.91 | -.61 | t (4-5) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.473** | **NS 0.654** | **0.00** | **NS 0.976** | **0.00** | **NS 0.242** | **NS 0.365** | **NS 0.541** | **Sig** |
| **5** | Mean | 10.50 | 142.78 | 34.13 | 145.40 | 97.12 | 142.64 | 4.15 | 5.90 | 1.82 | 1.00 | 0.67 | Mean |
| n | Stdev | 0.17 | 7.10 | 8.78 | 14.00 | 10.88 | 9.95 | .30 | .44 | .41 | .06 | .10 | Stdev |
| 93 | t (5-6) | -22.57 | -6.90 | -4.06 | -2.85 | -2.58 | -6.62 | 4.45 | -2.86 | 4.09 | -2.48 | -.42 | t (5-6) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **0.00** | **0.01** | **0.00** | **0.00** | **0.00** | **0.00** | **0.01** | **NS 0.677** | **Sig** |
| **6** | Mean | 11.50 | 149.40 | 39.08 | 150.71 | 101.54 | 152.79 | 3.99 | 6.07 | 1.62 | 1.02 | 0.67 | Mean |
| n | Stdev | 0.40 | 6.92 | 8.99 | 13.32 | 13.59 | 12.06 | .25 | .41 | .33 | .07 | .12 | Stdev |
| 125 | t (6-7) | -20.65 | -4.56 | -2.62 | -2.43 | -2.61 | -5.07 | 3.87 | -1.93 | 2.23 | -2.65 | -.77 | t (6-7) |
| | **Sig** | **0.00** | **0.00** | **0.01** | **0.01** | **0.01** | **0.00** | **0.00** | **NS 0.055** | **0.02** | **0.00** | **NS 0.433** | **Sig** |
| **7** | Mean | 12.50 | 154.38 | 42.44 | 155.63 | 106.85 | 161.88 | 3.84 | 6.18 | 1.52 | 1.05 | 0.69 | Mean |
| n | Stdev | 0.21 | 8.52 | 8.73 | 15.09 | 14.88 | 12.98 | .29 | .36 | .31 | .06 | .12 | Stdev |
| 78 | t (7-8) | -19.68 | -6.77 | -5.37 | -1.88 | 2.31 | -3.37 | .07 | -4.01 | 4.13 | 1.84 | 2.62 | t (7-8) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.062** | **0.02** | **0.00** | **NS 0.947** | **0.00** | **0.00** | **NS 0.068** | **0.01** | **Sig** |
| **8** | Mean | 13.50 | 164.02 | 50.98 | 160.30 | 101.92 | 168.78 | 3.84 | 6.45 | 1.33 | 1.03 | 0.65 | Mean |
| n | Stdev | 0.41 | 9.90 | 11.59 | 17.18 | 13.14 | 13.74 | .24 | .50 | .29 | .07 | .12 | Stdev |
| 95 | t (8-9) | -20.04 | -3.57 | -3.74 | 1.97 | .68 | -3.31 | -2.35 | -5.55 | 2.61 | -.75 | -.35 | t (8-9) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **0.05** | **NS 0.496** | **0.00** | **0.02** | **0.00** | **0.01** | **NS 0.454** | **NS 0.723** | **Sig** |
| **9** | Mean | 14.51 | 169.15 | 57.09 | 155.53 | 100.59 | 175.22 | 3.93 | 6.86 | 1.23 | 1.04 | 0.65 | Mean |
| n | Stdev | 0.16 | 8.41 | 8.97 | 13.29 | 11.85 | 10.79 | .26 | .45 | .17 | .07 | .10 | Stdev |
| 74 | t (9-10) | -18.44 | -7.32 | -5.75 | .75 | -.07 | -3.72 | -.65 | -4.37 | 4.39 | 1.23 | -.62 | t (9-10) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.452** | **NS 0.943** | **0.00** | **NS 0.514** | **0.00** | **0.00** | **NS 0.219** | **NS 0.537** | **Sig** |
| **10** | Mean | 15.51 | 176.49 | 64.31 | 154.03 | 100.71 | 181.28 | 3.95 | 7.13 | 1.13 | 1.03 | 0.66 | Mean |
| n | Stdev | 0.45 | 6.64 | 9.06 | 14.71 | 12.51 | 12.10 | .27 | .43 | .16 | .06 | .11 | Stdev |
| 172 | t (10-11) | -12.80 | -2.07 | -3.00 | 1.39 | .60 | -1.14 | -1.62 | -3.21 | 1.67 | -.02 | -.46 | t (10-11) |
| | **Sig** | **0.00** | **0.04** | **0.00** | **NS 0.165** | **NS 0. 551** | **NS 0.254** | **NS 0.107** | **0.00** | **NS 0.096** | **NS 0.980** | **NS 0.648** | **Sig** |
| **11** | Mean | 16.50 | 178.98 | 69.37 | 150.16 | 99.32 | 183.85 | 4.04 | 7.38 | 1.08 | 1.03 | 0.67 | Mean |
| n | Stdev | 0.11 | 5.52 | 9.23 | 16.25 | 12.95 | 12.10 | .29 | .30 | .14 | .06 | .11 | Stdev |
| 35 | t (11-12) | -12.54 | -1.14 | -.85 | -1.11 | .06 | -.85 | .88 | .11 | .90 | -.26 | .73 | t (11-12) |
| | **Sig** | **0.00** | **NS 0.025** | **NS 0.395** | **NS 0.270** | **NS 0.955** | **NS 0.395** | **NS 0.380** | **NS 0.913** | **NS 0.369** | **NS 0.793** | **NS 0.468** | **Sig** |
| **12** | Mean | 17.40 | 180.26 | 70.84 | 153.22 | 99.18 | 185.65 | 3.99 | 7.37 | 1.06 | 1.03 | .65 | Mean |
| n = 172 | **Stdev** | 0.42 | 6.16 | 9.29 | 14.64 | 13.37 | 11.23 | .28 | .41 | .14 | .06 | .11 | **Stdev** |

Table 2: Statistical characteristics of age, somatic and kinematic parameters of running stride over a 10-metre distance after a 15-metre flying start – GIRLS and significance of difference between the variables

| Group | Statistic | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | Speed | Relative speed | Relative stride length | Flight/ contact | Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Mean | 6.50 | 121.00 | 21.74 | 157.28 | 102.89 | 118.51 | 3.88 | 4.58 | 2.13 | .98 | .66 | Mean |
| n | Stdev | 0.17 | 3.77 | 2.67 | 13.89 | 14.37 | 8.66 | .31 | .38 | .30 | .06 | .11 | Stdev |
| 46 | t (1-2) | -17.07 | -6.37 | -3.77 | .94 | -1.32 | -4.35 | .32 | -3.59 | 1.54 | -1.29 | -1.71 | t (1-2) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0, 347** | **NS 0.188** | **0.00** | **NS 0.751** | **0.00** | **NS 0.125** | **NS 0.198** | **NS 0.089** | **Sig** |
| **2** | Mean | 7.51 | 126.50 | 23.94 | 154.96 | 106.51 | 125.73 | 3.87 | 4.83 | 2.05 | .99 | .6937 | Mean |
| n | Stdev | 0.39 | 5.41 | 3.63 | 14.59 | 16.56 | 10.05 | .32 | .43 | .30 | .07 | .13 | Stdev |
| 134 | t (2-3) | -23.55 | -10.24 | -7.05 | -.93 | -1.16 | -6.88 | 1.47 | -4.59 | 4.23 | -1.57 | -.43 | t (2-3) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.351** | **NS 0.245** | **0.00** | **NS 0.143** | **0.00** | **0.00** | **NS 0.118** | **NS 0.669** | **Sig** |
| **3** | Mean | 8.52 | 133.65 | 28.04 | 156.80 | 108.90 | 134.79 | 3.80 | 5.10 | 1.87 | 1.01 | .7004 | Mean |
| n | Stdev | 0.21 | 5.15 | 5.29 | 15.50 | 14.22 | 9.90 | .32 | .46 | .35 | .08 | .11 | Stdev |
| 101 | t (3-4) | -23.55 | -6.42 | -4.47 | 1.19 | -1.34 | -4.28 | .22 | -3.67 | 2.82 | -.87 | -1.85 | t (3-4) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.234** | **NS 0.182** | **0.00** | **NS 0. 828** | **0.00** | **0.05** | **NS 0.386** | **NS 0.066** | **Sig** |
| **4** | Mean | 9.50 | 138.48 | 31.60 | 154.56 | 111.41 | 140.94 | 3.79 | 5.32 | 1.75 | 1.02 | .7269 | Mean |
| n | Stdev | 0.42 | 6.47 | 6.94 | 14.79 | 15.52 | 12.33 | .31 | .49 | .35 | .07 | .12 | Stdev |
| 177 | t (4-5) | -12.72 | -3.64 | -2.65 | -.54 | -.54 | -2.49 | .73 | -1.72 | 1.56 | -.64 | -.36 | t (4-5) |
| | **Sig** | **0.00** | **0.00** | **NS 0.09** | **NS 0.592** | **NS 0.587** | **0.02** | **NS 0.464** | **NS 0.087** | **NS 0.121** | **NS 0.523** | **NS 0.716** | **Sig** |
| **5** | Mean | 10.52 | 143.36 | 35.46 | 156.26 | 113.16 | 147.16 | 3.75 | 5.49 | 1.64 | 1.03 | .7361 | Mean |
| n | Stdev | 0.12 | 7.41 | 8.61 | 19.88 | 17.59 | 11.85 | .32 | .53 | .41 | .07 | .15 | Stdev |
| 28 | t (5-6) | -11.15 | -4.83 | -2.76 | -1.69 | -.40 | -3.94 | 1.96 | -2.25 | 2.32 | -.84 | .78 | t (5-6) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.093** | **NS 0.693** | **0.00** | **NS 0.051** | **0.03** | **0.03** | **NS 0.402** | **NS 0.437** | **Sig** |
| **6** | Mean | 11.52 | 151.48 | 40.76 | 161.86 | 114.42 | 157.49 | 3.64 | 5.72 | 1.47 | 1.04 | .7153 | Mean |
| n | Stdev | 0.47 | 8.31 | 9.47 | 15.37 | 15.03 | 12.92 | .25 | .48 | .33 | .08 | .13 | Stdev |
| 153 | t (6-7) | -11.44 | -4.20 | -2.97 | -1.15 | -1.07 | -3.71 | 1.56 | -2.17 | 2.54 | -.90 | -.07 | t (6-7) |
| | **Sig** | **0.00** | **0.00** | **0.00** | **NS 0.250** | **NS 0.286** | **0.00** | **NS 0.120** | **0.03** | **0.02** | **NS 0.370** | **NS 0.941** | **Sig** |
| **7** | Mean | 12.50 | 158.19 | 46.10 | 165.39 | 117.56 | 166.77 | 3.57 | 5.92 | 1.31 | 1.05 | .7171 | Mean |
| n | Stdev | 0.12 | 7.03 | 7.07 | 16.41 | 14.24 | 11.53 | .29 | .46 | .23 | .06 | .11 | Stdev |
| 31 | t (7-8) | -10.91 | -2.60 | -2.07 | -.27 | 1.70 | .12 | -.93 | -.85 | 1.41 | 1.82 | 1.62 | t (7-8) |
| | **Sig** | **0.00** | **0.01** | **0.04** | **NS 0.788** | **NS 0.091** | **NS 0.908** | **NS 0.357** | **NS 0.395** | **NS 0.160** | **NS 0.071** | **NS 0.107** | **Sig** |
| **8** | Mean | 13.51 | 161.84 | 49.66 | 166.27 | 112.30 | 166.49 | 3.62 | 6.01 | 1.25 | 1.03 | .6808 | Mean |
| n | Stdev | 0.51 | 6.81 | 8.77 | 15.81 | 15.34 | 11.54 | .29 | .51 | .24 | .07 | .11 | Stdev |
| 104 | t (8-9) | -15.60 | -4.45 | -3.05 | 1.77 | 1.28 | -.73 | -2.08 | -2.58 | 2.18 | 1.82 | .12 | t (8-9) |
| | **Sig** | **0.00** | **0.01** | **0.00** | **NS, 0.079** | **NS 0,203** | **NS 0.464** | **0.04** | **0.02** | **0.03** | **NS 0.070** | **NS 0.905** | **Sig** |

| Group | Statistic | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | Speed | Relative speed | Relative stride length | Flight/ contact | Statistic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **9** | Mean | 14.51 | 166.15 | 53.35 | 162.12 | 109.31 | 167.80 | 3.71 | 6.20 | 1.17 | 1.01 | .6788 | Mean |
| n | Stdev | 0.14 | 5.01 | 5.53 | 13.39 | 14.02 | 10.97 | .27 | .43 | .15 | .07 | .10 | Stdev |
| 66 | t (9-10) | -18.22 | -.20 | -2.05 | 1.61 | .78 | .90 | -1.67 | -1.00 | 1.27 | 1.11 | -.32 | t (9-10) |
| | **Sig** | **0.00** | **NS 0.839** | **0.04** | **NS 0,108** | **NS 0,434** | **NS 0.367** | **NS 0.097** | **NS 0.318** | **NS 0.203** | **NS 0.267** | **NS 0.747** | **Sig** |
| **10** | Mean | 15.50 | 166.31 | 55.05 | 159.14 | 107.87 | 166.57 | 3.77 | 6.26 | 1.15 | 1.00 | .6834 | Mean |
| n | Stdev | 0.44 | 4.83 | 6.17 | 13.54 | 13.32 | 9.70 | .25 | .40 | .14 | .05 | .11 | Stdev |
| 279 | t (10-11) | -16.38 | -.43 | -1.44 | -1.36 | .54 | -.10 | .70 | .64 | 1.56 | .12 | 1.03 | t (10-11) |
| | **Sig** | **0.00** | **NS 0,666** | **NS 0.150** | **NS 0.176** | **NS 0.588** | **NS 0.919** | **NS 0.484** | **NS 0.522** | **NS 0.119** | **NS 0.903** | **NS 0.304** | **Sig** |
| **11** | Mean | 16.50 | 166.67 | 56.42 | 161.89 | 106.74 | 166.72 | 3.75 | 6.22 | 1.12 | 1.00 | .6663 | Mean |
| n | Stdev | 0.12 | 4.83 | 6.94 | 13.02 | 15.89 | 9.88 | .23 | .36 | .14 | .06 | .13 | Stdev |
| 52 | t (11-12) | -15.19 | -.91 | -1.33 | .05 | .63 | 1.66 | -.66 | 1.02 | 1.95 | 2.25 | .63 | t (11-12) |
| | **Sig** | **0.00** | **NS 0.365** | **NS 0.184** | **NS 0.958** | **NS 0.528** | **NS 0.098** | **NS 0.512** | **NS 0.310** | **NS 0.052** | **.02** | **NS 0.527** | **Sig** |
| **12** | Mean | 17.47 | 167.41 | 57.68 | 161.79 | 105.18 | 163.90 | 3.77 | 6.15 | 1.08 | .98 | .65 | Mean |
| n=197 | Stdev | 0.46 | 5.33 | 5.76 | 12.14 | 15.88 | 11.14 | .25 | .42 | .13 | .06 | .11 | Stdev |

The values of the flying phase duration can be studied in Figure5. Their course is parallel among both the boys and girls with a tendency to lengthen the duration up until 12.5 years of age, followed by a slightly shortening tendency till 17.5 years of age. The course of the efficiency index in Figure 6 is similar. It is clear that these parameters confirm the high level of ontogenetic stability (duration of the support phase and the flying phase, flying phase and support phase ratio and frequency) compared to unstable parameters such as running speed and stride length, which are dependent on age.

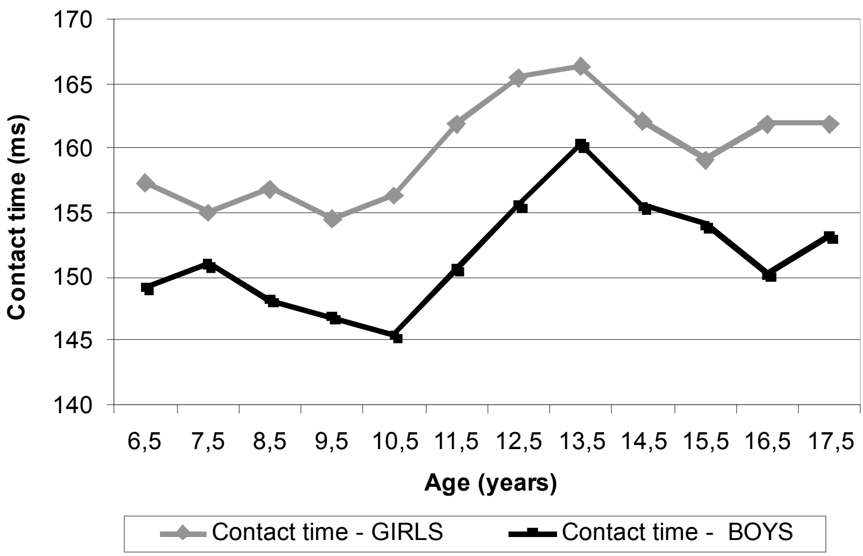


Figure 4: Average contact time over the 10-metre distance after a 15-metre flying start

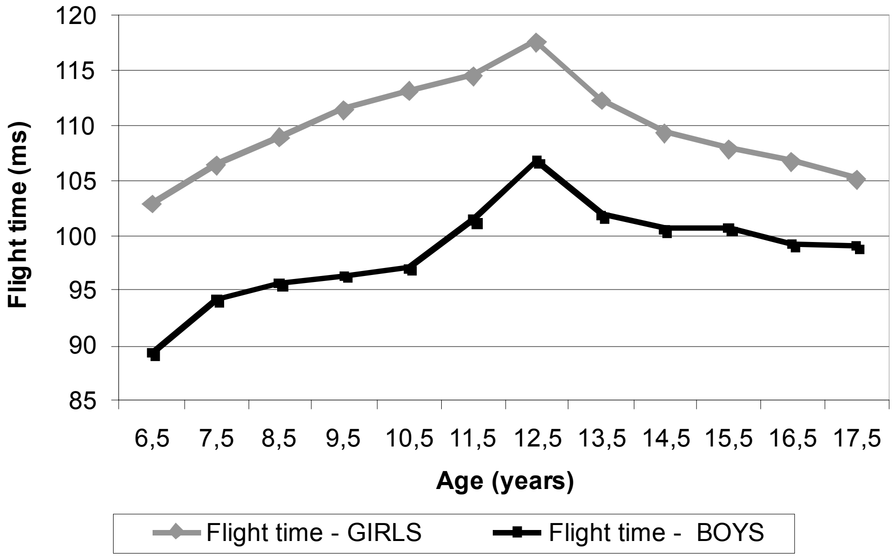


Figure 5: Average flight time over the 10-metre distance after a 15-metre flying start

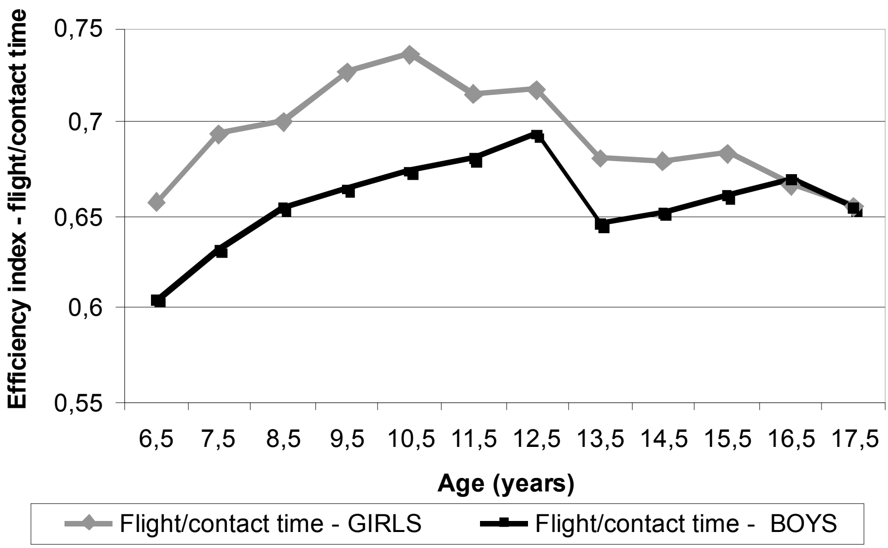


Figure 6: Efficiency index – defined by the duration of the support phase and the running phase ratio

Relationship analysis in the form of Pearson's correlation coefficients, as shown in Table 3, confirmed the statistically significant dependence of running speed, indicators of decimal age, body height, body weight, duration of the support phase and the flying phase, stride length and stride frequency (girls); relative speed, relative frequency and efficiency index (boys). The results for both sexes showed that the structure of the sprint stride changes drastically in connection to the stride length and frequency, the ratio between the contact and the flight phase

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Table 3: Correlation coefficients and their significances of age, somatic and kinematic parameters of the 10-metre run after a 15-metre flying start

p<0.01**
p<0.05*

| | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | Speed | Relative speed | Relative stride frequency | Flight/ contact | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decimal age | 1 | .937** | .889** | .141** | .150** | .885** | -.238** | .878** | -.783** | .304** | .036 | Decimal age |
| Body height | .909** | 1 | .934** | .248** | .174** | .911** | -.337** | .851** | -.863** | .243** | .002 | Body height |
| Body weight | .882** | .924** | 1 | .280** | .082** | .820** | -.292** | .773** | -.916** | .157** | -.081** | Body weight |
| Contact time | .153** | .257** | .264** | 1 | .122* | .188** | -.687** | -.159** | -.439** | .042 | -.623** | Contact time |
| Flight time | -.053* | .001 | -.082** | .049 | 1 | .415** | -.628** | .136** | -.096** | .653** | .840** | Flight time |
| Stride length | .749** | .839** | .732** | .171** | .315** | 1 | -.463** | .880** | -.716** | .617** | .214** | Stride length |
| Stride frequency | -.089** | -.203** | -.147** | -.674** | -.696** | -.370** | 1 | .005 | .426** | -.448** | -.125** | Stride frequency |
| Speed | .736** | .755** | .681** | -.240** | -.111** | .812** | .235** | 1 | -.589** | .456** | .182** | Speed |
| Relative speed | -.797** | -.863** | -.928** | -.428** | .001 | -.634** | .324** | -.472** | 1 | .032 | .158** | Relative speed |
| Relative stride frequency | -.082** | -.069* | -.140** | -.106** | .574** | .482** | -.347** | .278** | .229** | 1 | .522** | Relative stride frequency |
| Flight/ contact | -.129** | -.138** | -.211** | -.565** | .835** | .160** | -.211** | 0.03 | .230** | .521** | 1 | Flight/ contact |
| | Decimal age | Body height | Body weight | Contact time | Flight time | Stride length | Stride frequency | Speed | Relative speed | Relative stride frequency | Flight/ contact | |

BOYS (above diagonal); GIRLS (below diagonal) and the vertical pressure on the surface. The correlation coefficients reveal that the duration of contact, the relative stride frequency and the vertical pressure on the surface are good indicators of the sprinting potential of young runners.

The results of our research can be used as background papers concerned with the assessment of the level of talent for running speed. An individual can be considered talented if they achieve parameters of two standard deviations above the mean values for indicators such as stride frequency, duration of the support phase and running speed. It may contribute to a better understanding of the factors responsible for sprint performance in the population of athletes who are not top-level sprinters, i.e. they may be useful to PE teachers, coaches who work with novices in athletics and physical conditioning coaches who work in sports other than athletics, to gain a more thorough insight into the mechanisms of sprinting efficiency.

## DISCUSSION

The stride frequency was revealed to be a very stable parameter and only significantly changes during the prepubescent period. This can be explained by the deterioration of co-ordination which is a result of an increase in body height and weight. Moreover, Čoh, Jošt, Kampmiller, and Štuhec (2000) found that the development of maximal speed is not constant, but has certain oscillations, particularly in the period of adolescence when the morphological and motor characteristics of youth change. Due to the acceleration of longitudinal parameters, the frequency and length of the stride change. The length of the stride increases and the frequency of the stride decreases significantly. Frequency not only changes as a result of morphological changes but also due to the disruption of proprio-receptive mechanisms for movement control.

In contrast to our duration of contact results the study by Bračič, Tomažin, and Čoh (2009) has been published which established that the biggest differences in the development of the maximal speed of pupils of both genders occurs between the ages of 12 and 14, mainly in boys due to the development of strength. The duration of the contact phase of the sprinting stride in boys reduces rapidly after the age of 12. However, others like Mero et al. (1986 and 1992) consider the duration of contact phase as one of the main criteria for selecting young sprinters.

These results are comparable to older research by Kampmiller and Koštial (1986) carried out with smaller samples and modified methods at school stadiums where achieving a high level of standard measurement conditions was not possible. That is why our results are influenced by the new method. For example, the support phase is 0.02 s longer than measured in the past, also in comparison with the values of kinematic parameters of the support phase identified by other authors like Čoh et al. (1994) where they found the most important kinematic-dynamic parameters, their developmental trend and their influence on the efficiency in maximal sprinting speed for young sprinters of both sexes, from 11 to 18 years of age. They also recorded kinematical and dynamical parameters with an electronic device – a locomometer.

It was also determined that stride length and stride frequency were negatively correlated during maximal speed running due to the positive correlation between skeleton dimensionality and stride length on one hand, and the negative correlation between skeleton dimensionality and stride frequency. As far as the authors know, the research integrally demonstrated the mechanism of the mutual relationships between subcutaneous fatty tissue, skeleton dimensionality, explosive power and kinematic parameters (Babić & Dizdar, 2010).

## CONCLUSIONS

The results of the research into the kinematic characteristics of the running step in the population of 7- to 18-year-old youth allow us to present the following conclusions:

Running speed measured on a 10-metre track with a 15-m approach (flying start) has a linear growth tendency in the male population up until 13 years of age, followed by a phase of an even steeper increase. In the female population after 14 to 15 years of age there is an observable stagnation of the running speed/velocity. A similar age dependence was detected while assessing the length of the running step.

A high level of ontogenetic stability and independence from age was determined in kinematic parameters (stride frequency, duration of the support phase, duration of the flight phase, and partly the efficiency index). These indicators may be considered the predictors of running speed. A partial deterioration of the kinematic parameters occurs in the prepubescent and pubescent periods.

Regarding specific implications for practice, based on our results we suggest evaluating the level of running speed talent on the basis of stride frequency and duration of the support phase. If a child achieves above-average values in the aforesaid parameters that are 2 or 3 standard deviations higher than the population average determined in our research, an individual may be considered as talented.

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