Journal of Human Kinetics volume 18 2007, 109-120

Somatic and Fitness Endowment of Sprinting Stride in the Context of Developmental Changes and Diverse Sport Activities

by

Marzena Paruzel–Dyja[1], Janusz Iskra[1], Adam Zając[2]

The aim of the study was to evaluate somatic and fitness variables determining sprinting strides in the context of developmental changes and diverse sport activities. Additionally, the changes of sprinting stride variables were observed in three periods of an annual training cycle of the best Polish sprinters.

The research material consisted of four groups: first year female and male students of Physical Education in Katowice, sprinters from the Polish National Team, 10 – 11 year old boys and girls from a Primary School, 10 – 11 year old children attending track and field training sessions six times a week.

Stride variables were measured on the basis of a 30 m run (for children) or 100 m run (students and athletes) with the use of a cinematographical method. Somatic evaluations were done on the basis of chosen anthropometrical variables, with the use of standard research procedures and devices. In the group of students four field tests were carried out: the 100 m and 400 m run, 4 kg shot throw backwards and standing triple jump.

The analysis revealed that both variables of a sprinting stride changed according to the velocity of the race. Stride frequency of high level sprinters differed in successive periods of preparation, while stride length was similar.

Sprinting stride variables of students depended on the length of their lower limbs. The length of the running stride was determined by the level of explosive strength of the lower and upper limbs and anaerobic endurance, while stride frequency depended only on the level of anaerobic endurance.

Key words: *sprinting, velocity, stride frequency, stride length*

[1] - *Department of Track and Field, Academy of Physical Education in Katowice, Poland*
[2] - *Department of Sports Training, Academy of Physical Education in Katowice, Poland*

Introduction

Sprint races seem to be the simplest track and field events from the technical point of view, however proper technique of running enables an athlete to achieve high sport results. Scientists claim that stride length and frequency are the most important variables determining the velocity of the run.

Stride frequency is one of the speed indicators, measured by the maximal number of movements performed by a particular group of muscles in a given unit of time. It is probably connected with the mobility of the nervous system (Sozański and Witczak 1981, Ryguła 2000). The frequency of the running stride is defined as the number of strides performed during one second.

Stride length is a distance between toes of one leg being in the support phase and the footprint of the swinging leg during landing.

Stride frequency is a number of strides performed during 1 s.

Running stride variables were a subject of analysis of many authors, however concentrating mainly on high level sprinters (Hoffmann 1971, Mann 1981, Donati 1995, Letzelter 1999, Jarver 2004).

The aim of the study was to determine somatic and fitness variables of sprinting strides in the context of developmental changes and diverse sport activities. Additionally, the changes of stride variables were observed in three periods of sports preparation of the best Polish sprinters.

The following research hypotheses were formed:

1. Both stride variables change according to the velocity of sprinting.
2. Stride length and frequency of high level sprinters differs in successive periods of an annual training cycle
3. Sprinters' stride characteristics depend on anthropometric variables.
4. A one year long track and field training cycle may influence stride variables of 10 – 11 year old children. Probably these changes may be more visible in comparison to untrained subjects.
5. Running stride variables are determined by the level of explosive strength of the lower limbs and anaerobic endurance.

Material and methods

The research was carried out in four groups (tab. 1).

In order to verify the assumed research hypothesis, the observation method was used as well as a year – long pedagogical experiment. Among the subjects there were pupils of the 4th and 5th grades, attending standard PE lessons as well as children form track and field classes. The tests were carried out twice within a year.

Table 1

The research material

	Group	n
1.	Elite Polish sprinters, members of the Olympic National Team in Athens 2004	11
2.	Students of the 1st year of Physical Education in Katowice	184
3.	Boys aged 10 – 11 – years from the Primary School No. 15 in Ruda Slaska	68
	Girls aged 10 – 11 – years from the Primary School No. 15 in Ruda Slaska	73
4.	Boys aged 10 – 11, from the Primary School No. 15 in Ruda Slaska, attending track and field trainings.	18
	Girls aged 10 – 11, from the Primary School No. 15 in Ruda Slaska, attending track and field trainings.	16

Stride variables were compared in relation to different sports level, anthropometric data, fitness level, and training period.

In the group of sprinters from the National Team, stride variables and velocity was the subject of investigation in three periods of the annual training cycle: in the general preparation period (December), special preparation period (April) and in the competition period (June), on the basis of a 60 m race from a high start.

Stride variables were measured on the basis of a 30 m run (children) or 100 m run (students and athletes) from a crouch start, on a synthetic track. The time of the race was measured electronically. All the races were registered by a digital video camera recorder (Panasonic NV–DS77). The analysis of video recordings enabled to count the number of strides during the distance, the average stride length and stride frequency (cinematographical method).

An identical procedure of stride analysis during the most important world competitions was used by many authors, among them Vittori and Donati (1985) and Letzelter 1999).

In the group of students and in chosen groups of children, the results registered with the cinematographic method was additionally evaluated by a laser measuring system LDM 300C – Sport (Jena Optic, Jena, Germany). This device enables a precise evaluation of velocity changes at a chosen distance (Sanderson at al. 1991, Türk-Noack 1996). The correlations of the results of above mentioned methods confirmed the reliability of the cinematographic method (r=0,87).

Somatic evaluation was performed on the basis of chosen anthropometrical variables with the use of standard research procedures and devices (Malinowski and Bożiłow 1997), applied previously in Iskra' s research (2001).

For the purpose of the students' fitness preparation assessment, the following tests were used:

- 100 m run from a crouch start (test of a running speed),
- 4 kg shot throw backwards (test of a dynamic strength of the shoulder girdle),
- Standing triple jump (test of a dynamic strength of the lower limbs),
- 400 m run from a high start (test of an anaerobic endurance).

Before beginning the statistical analysis, the reliability of the used research devices (especially the measurements of both stride variables and the time of the race) was evaluated. In measuring stride length with the use of a video camera, the correlation factor of two repetitions of the same trial (a 30 m run; r=0,94) and between the measurements done by two subjects during the same trials (r=0,96) was calculated. In may be stated that the used method of stride length and frequency evaluation as well as the time measurement time comply with the reliability criterion.

The collected data was described by commonly used statistical methods: arithmetic mean, standard deviations and minimal and maximal values.

The relationships between the variables of the running stride and the results of fitness tests, as well as somatic variables were evaluated with the use of Pearson's analysis of correlation, taking into consideration three levels of significance: 0,05, 0,01 and 0,001.

The changes in stride variables in three training periods of high level sprinters were assessed on the basis of analysis of variance (ANOVA).

Results

Table 2 presents the results of sprint race analysis of elite Polish sprinters and two groups of students, diversified in regard to the level of speed. Sprinters from the Polish Olympic team, had a much greater running speed and higher values of both measured stride variables. The shortest strides and the lowest frequency (1,87 cm and 4,04 steps/s) was achieved by students with the lowest velocity.

While there were significant differences between the average length of a stride in the analysed groups ($p \leq 0,001$), stride frequency did not differentiate significantly the groups of sprinters and students of group A. Significant differences were seen between the sprinters and group B ($p \leq 0,05$), as well as between the students reaching a higher and lower level of speed ($p \leq 0,001$).

Table 2

Sprint velocity and stride variables of elite Polish sprinters and two groups of PE students

Variable	A (n=11)	B (n=90)	C (n=90)	F	ANOVA		
					A-B	A-C	B-C
Velocity (m/s)	9,74 ±0,18[1)]	8,16 ±0,21	7,79 ±0,09	464,28***	***	***	***
Stride length (m)	2,22 ±0,10	1,93 ±0,12	1,87 ±0,10	35,86***	***	***	***
Stride frequency (1/s)	4,40 ±0,18	4,21 ±0,25	4,04 ±0,21	17,31***	n.s.	*	***

[1)] $\overline{X}$ ± standard deviation * p≤0,05; ** p≤0,01; *** p≤0,001

A – sprinters, B – students with a higher velocity , C – students with a lower velocity of the run

Both stride variables of sprinters had a high influence on their results in sprinting (in the competition period), but stride frequency was much more significant (fig.2). Among students a statically significant relation was observed between stride frequency and velocity of the race (p≤0,01). However, the stride length of the subjects had no statistically significant meaning.

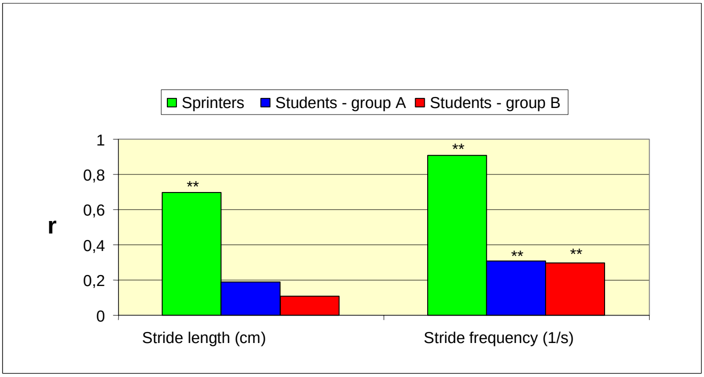

Fig. 1

*The influence of stride variables on velocity of elite Polish sprinters and Physical Education students ** p≤0,01*

The next stage of the analysis included comparison of sprinters' stride length and frequency values in three periods of an annual training cycle. The research revealed statistically significant differences of velocity (F=28,90, p≤0,01) and stride frequency (F=6,09, p≤0,01) in each of the three training periods. The length of the stride was similar from the wintertime to summer (F=1,03). Detailed data is shown in table 3.

Table 3

The changes of velocity and stride variables in various periods of a training cycle

Variable	December			April			June			F
	$\bar{x}$	SD	min/ max	$\bar{x}$	SD	min/ max	$\bar{x}$	SD	min/ max	
Velocity (m/s)	8,72	0,10	8,55/ 9,09	8,88	0,10	8,76/ 9,03	9,10	0,13	8,95/ 9,32	28,90**
Stride length (m)	2,11	0,10	1,99/ 2,20	2,04	0,10	1,90/ 2,15	2,07	0,09	1,94/ 2,18	1,03
Stride frequency (1/s)	4,14	0,13	3,98/ 4,35	4,35	0,18	4,14/ 4,65	4,40	0,18	4,18/ 4,65	6,09*

* p ≤ 0,05, ** p ≤ 0,01

It was proven, that sprinters' race velocity in various periods of an annual training cycle depended on both stride length and frequency. In the wintertime stride frequency was more significant (r=0,89; p≤0,01), while in the spring stride length was of greater importance (r=0,67; p≤0,05). In the competition period both of the variables had a significant influence on sprint results, but the significance of stride frequency was more substantial (Fig.2).

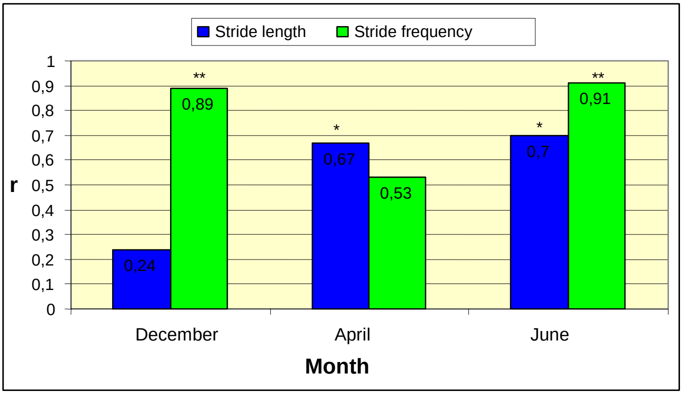

Fig. 2

Correlation coefficients between velocity and stride variables of elite sprinters in various periods of a training cycle * p≤0,05, ** p≤0,01*

Among many anthropometric variables, body height and length of the lower limbs seem to be the factors determining the length and frequency of strides as well as the velocity of sprinting. In order to evaluate these dependencies, the research was conducted among students of a first year of Physical Education from Katowice, which were divided into 3 subgroups. Group A consisted of men having the longest lower limbs, group B was comprised of subjects having an average value of this variable. Group C consisted of students with the shortest lower limbs (tab. 4).

Table 4

Sprinting stride variables of three groups of students diversified with regard to the length of the lower limbs

Variable	A (n=61)	B (n=61)	C (n=61)	F	ANOVA		
					A-B	A-C	B-C
Velocity (m/s)	7,84	7,74	7,79	1,40	n.i.	n.i.	n.i.
Stride length (m)	1,95	1,88	1,67	11,24***	***	***	n.i.
Stride frequency (1/s)	4,04	4,13	4,19	6,16**	n.i.	**	n.i.

** p≤0,01; *** p≤0,001; A – students with the biggest length of lower limbs, B – students with an average length of lower limbs, C – students with the smallest length of lower limbs.

The analysis of the results showed that sprinting velocity in the three groups of students was similar, regardless of the length of the lower limbs. Stride frequency was lowest in group A and highest among students with the shortest limbs, however statistically significant differences were noticed only between group A and C. The opposite situation occurred in case of the length of the strides performed during sprinting, which were highest in the group of students with the greatest length of the lower limbs and the smallest in group C, however significant differences occurred only between group A and C as well as A and B (p≤0,001).

Another experiment evaluating the scope of changes of sprinting stride variables after a year was carried out in the group of children aged 10-11. Additionally an attempt was made to define the influence of sport activities on these changes (tab. 5).

After a year, in all examined groups, regardless of the gender and the level of sport activities, the average stride length increased, with a simultaneous, slight reduction of stride frequency. Among boys of the two groups, statistically significant changes were found only in case of stride length (8 cm; p≤0,05). In the group of girls attending Physical Education lessons with a standard program, the most significant changes concerned stride length (p≤0,001) and velocity (p≤0,01). After an annual track and field training program in the group of girls, a statistically significant improvement of stride length was observed (o 7 cm; p≤0,05), just as in the group of their contemporaries.

Table 5

The changes of stride variables of trained and untrained children aged 10 – 11

Variable		Boys (n=68)			Girls (n=73)		
		10 [1)]	11	F	10	11	F
Time of the 30 m race (s)	N	6,22±0,66	6,06±0,61	2,16	6,37±0,49	6,15±0,44	8,76**
	T	5,91±0,49	5,69±0,33	2,42	6,07±0,35	5,88±0,25	3,02
Stride length (m)	N	1,25±0,12	1,31±0,12	10,58**	1,30±0,09	1,38±0,10	25,51***
	T	1,31±0,08	1,39±0,08	5,76*	1,35±0,09	1,42±0,10	4,27*
Stride frequency (1/s)	N	3,92±0,33	3,83±0,32	2,75	3,66±0,27	3,59±0,27	2,70
	T	3,89±0,25	3,83±0,32	0,38	3,66±0,27	3,63±0,26	0,48

* p≤0,05; ** p≤0,01; *** p≤0,001; [1)] age

An attempt to evaluate the influence of fitness level on sprint race variables was made on the basis of the students' group. For the purpose of data analysis, Pearson's linear correlation was applied (Pic.3).

It was shown, that students' stride length was determined by the level of explosive strength of the lower limbs (p≤0,01), upper limbs and trunk's strength (p≤0,01) as well as anaerobic endurance (p≤0,05). Stride frequency appeared as a variable dependent only on the level of anaerobic endurance (p≤0,001).

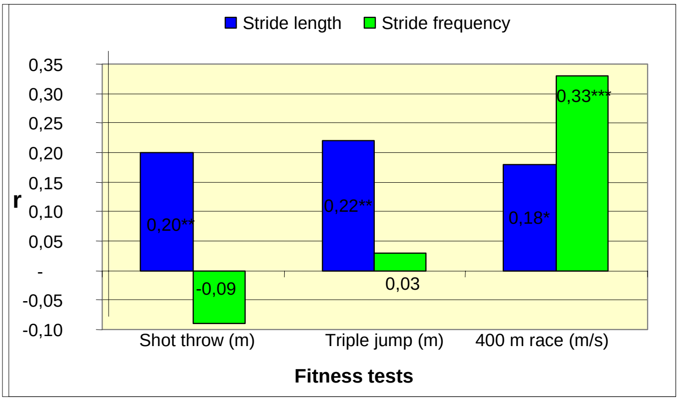

Fig. 3

Correlation coefficients between students' stride length and frequency and the level of motor fitness * p≤0,05; ** p≤0,01; *** p≤0,001

Discussion

According to many authors (Sinning and Forsyth 1970, Bosco and Vittori 1986, Shi and Tong 2003, Jarver 2004, Young 2005) running speed is a function of stride length and frequency, and faster speeds are achieved when one or both of the stride variables increase. However one has to remember that these variables are in close relation, what means that while one of them increases the other often decreases. However it is important to find an optimal balance between them.

Boughman (1984) claims that speed is a product of three factors: stride frequency, stride length and anaerobic endurance. With a proper training program, an athlete can enhance his performance level by improving each of these factors. The research done by Lopez (1981) revealed that while stride frequency is mainly genetically determined, stride length could be improved by strength training, bounding drills, uphill running and flexibility exercise.

The analysis of results carried out among students and sprinters show, that not only sprint velocity is highly influenced by stride variables but on the contrary, stride length and frequency are determined by the sport's level. It was also proven, that among these two variables it was stride frequency that had a more significant influence on results in sprinting, regardless of sport's level.

Some previous studies (Weyand at all 2000, Young 2005) indicate that stride length as well as stride frequency of elite sprinters may be increased by greater force applied at ground contact.

The research carried out among students of Physical Education indicate, that explosive strength of lower limbs as well as explosive strength of the upper limbs and anaerobic endurance had a significant impact on stride length, while stride frequency was determined by anaerobic endurance.

Mann (1981) states that the best sprinters are capable of increasing stride frequency by increasing muscle strength and improvement of running technique.

The experiment conducted in the group of elite Polish sprinters during an annual training cycle revealed statistically significant differences of sprint velocity as well as stride frequency, while stride length was similar in different training periods. The significance of these stride variables changes during the annual training cycle. In the general preparation period stride frequency is more important, the meaning of stride length grows in the specific preparation period, while during the competition period both variables determine results in sprinting with a domination of stride frequency. The analysis shows that each of the three periods of preparation is characterized by a different structure of sprinting stride. It is probably a result of specific training programs in each of these periods. Means of strength – endurance character predominate in the preparation period, while in December training sessions are based on the segments of distance within 300 – 400 m, run with long, natural strides, what may be seen in quite large stride length and low stride frequency. In the specific preparation period sprinters perform mainly speed – endurance and so called "speed – technique" (sub–maximal velocity) training sessions, what contributes to a gradual increase of stride frequency and an initial reduction of stride length. In the competition period speed and technique training dominate, maximal velocity increases and stride length and frequency become optimal for each athlete.

The opinions of various authors about the significance of somatic variables in sprinting differ significantly (Kobielski 1972, Sozański and Witczak 1981, Iskra 2001). Most of them agree that anthropometric variables do not correlate directly with running speed, but may be in close relation with stride length (Iskra 2001).

The study carried out in the group of students with various length of lower limbs shows, that sprinters with different body build may achieve similar results. The difference lies in the way they attain it. Students with shorter lower limbs run with higher frequency (of 0,15 step/s) and shorter strides (about 28 cm) than their counterparts with longer lower limbs.

Another interesting problem concerns the changes of stride variables during the ontogenesis and the influence of increased sports activity on these changes.

The experiment shows that between the age of 10 and 11, stride length increases with a simultaneous slight reduction of stride frequency, regardless of gender and level of sport activities. Probably in the context of stride variables in this period of development, the impact of a natural biological development is more significant than the influence of sport's training.

A comparable opinion was presented by Sozanski and Witczak (1981), who stated that the development of running speed is a natural consequence of normal biological development. According to the authors, a similar tendency is observed in case of stride length.

In the continuous, longitudinal studies of 11 – 15 year old boys (Paruzel and Walaszczyk 2003), an improvement of velocity as well as stride length was seen in each year of the research. A significance of stride length in the context of velocity improvement was also confirmed.

Conclusions

1. Both stride variables change according to sprint velocity.

2. Stride frequency of high level sprinters differs significantly in successive periods of preparation, while stride length remains unchanged.
3. Students' sprinting stride characteristics depend on the length of their lower limbs.
4. An annual track and field training of 10–11 year old children has no influence on the changes of running stride variables. The changes of these variables are similar regardless of sport activities and depend mostly on the natural biological development.
5. Stride length is determined by the level of explosive strength of the lower and upper limbs and anaerobic endurance, while stride frequency depends on the level of anaerobic endurance.

References

Bosco C., Vittori C. 1986. Biomechanical characteristics of sprint running during maximal and supra-maximal speed. *New Studies in Athletics* 1, 39 – 45.

Bougman M., Takaha M., Tellez T. 1984. Sport training. *National Strength and Conditioning Association Journal*, 3, 34 – 36.

Donati A. 1995. The development of stride length and stride frequency in sprinting. *New Studies in Athletics* 1, 51 – 66.

Hoffmann K. 1971. Stature, leg length, stride frequency. *Track Technique* 46, 1463 – 1469.

Iskra J. 2001. *Morfologiczne i funkcjonalne uwarunkowania rezultatów w biegach przez płotki.* Akademia Wychowania Fizycznego, Katowice

Jarver J. 2004. *Sprint and relays. Contemporary theory, technique and training*. Tafnews Press, Mountain View.

Kobielski B. 1972. Rytm biegu i długość kroków sprinterów polskich. *Sport Wyczynowy* 6, 18 –20.

Letzelter S. 1999. Schrittgestaltung beim 100 m Lauf fallen Weltmeisterschaften '97 und '99. *Leichtathletik* 9, 19 – 22.

Lopez V. 1981. Speed development. Stride length and frequency. *Track and Field Quarterly Review* 2, 25.

Malinowski A., Bożiłow W. 1997. *Podstawy antropometrii. Metody, techniki, normy*. Wydawnictwo Naukowe Państwowe Wydawnictwo Naukowe, Warszawa – Łódź.

Mann R. 1981. A kinetic analysis of sprinting. *Medicine and Science in Sports and Exercise* 5, 325 – 328.

Paruzel M., Walaszczyk A. 2003. Zmiany szybkości biegowej a długość kroku biegowego w badaniach ciągłych 11 – 15 – letnich chłopców. W: *Kierunki Doskonalenia Treningu i Walki Sportowej*, (red. H. Sozański, K. Perkowski, D. Śledziewski), Akademia Wychowania Fizycznego, Warszawa, 209 – 210.

Ryguła I. 2000. *Elementy teorii, metodyki, diagnostyki i optymalizacji treningu sportowego*. Akademia Wychowania Fizycznego, Katowice

Sanderson L.K., Mc Clements J., Gander R.E. 1991. *Development of apparatus to provide immediate accurate feedback to sprinters in the normal training environment*.

Shi D., Tong Y. 2003. The effects on stride length and frequency on the speeds of elite sprinters. *Track Coach* 163, 5218.

Sinning W.E., Forsyth H.L. 1970. Lower limb actions while running at different velocities. *Medicine and Science in Sports* 2, 28 – 34.

Sozański H., Witczak T. 1981. *Trening szybkości*. Sport i Turystyka, Warszawa.

Tűrk – Noack U. 1996. Pomiary prędkości w konkurencjach sprinterskich, skokach i biegach lekkiej atletyki przy pomocy nowego laserowego systemu pomiarowego LAVEG. *Lekkoatletyka* 6, 24 – 26.

Vittori C., Donati G.-F. 1985. Analisi ritmica della finale dei 100 m alle Olimpiadi di Monaco '72 vinta da Valery Borzov. Proposta di un modello metodologico di indagine. *Atleticastudi* 2, 185 – 189.

Weyand P., Sternlight D., Bellizzi M., Write S. 2000. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *Journal of Applied Physiology* 89, 1991 – 2000.

Young M. 2005. Maximal Velocity Sprint Mechanics. *Track Coach,* 5723 – 5729.

Corresponding adress
Marzena Paruzel – Dyja
Department of Track and Field,
Academy of Physical Education in Katowice, Poland
72 a, Mikołowska str., Katowice, Poland
e-mail: m.paruzel@awf.katowice.pl
Mobile phone: +48 602 442 102
Fax: +48 32 2075372

Authors submited their contribution of the article to the editorial board.
Accepted for pinting in Journal of Human Kinetics vol. 18/2007 on October 2007.