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THE DEVELOPMENT OF RESULTS IN 100M AND 400M SPRINT RACES IN ATHLETES AGED FROM 6 TO 100

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Abstract

The 100 m race is not only a sports discipline but also a way of assessing an athlete's speed abilities. The run over the distance of 400 metres combines both speed and endurance (anaerobic) capacities. The purpose of the study was to evaluate the development of results in men's 100 and 400m sprint races, taking into account the best performance within the age from 6 to 100. By examining the course and the development of the world's leading sprinters' careers, the authors took into consideration their best final results achieved each year. They were assigned to three research protocols that included age, successive years of starts, and the period before and after their personal best.The results are presented with arithmetic means and standard deviations (SD). In the comparative analysis of groups of runners over various distances (100 and 400m), the percentage value (%) of the result in relation to the world record over the given distance was chosen as a common element. The research has shown that the age range from 20 to 31 in the 100m race and 20 to 29 in the 400m run respectively, are the best periods for continuation of a sports career suitable for the shortest and longest sprint distance at the highest world level. The development of speed abilities up to the age of 14 is similar to the scale of their regression after the age of 35. Knowledge concerning the change in sports performance level in relation to age provides the opportunity to predict the periods of peak performance in a given sports discipline. This enables a rational and proper planning of the training process.

Key words: *100m, 400m, ontogenesis, sports career development.*

Introduction

Effort abilities as a result of many years of development and training are of interest to many researchers dealing with issues concerning not only the theory but also the methodology of sports. A sports result is the consequence of many biological, social and training factors affecting the athlete. Sports achievements determine their prestige and social position; they are evidence of success. In recent years, we have witnessed record results in track and field speed disciplines, and the 100 and 400m races are interesting, also in terms of analyzing the development of results and the related course of sports careers.

The 100m race is not only a sports discipline but also a way of assessing an individual's speed. Although at a younger age groups this distance seems too long for speed assessment (Raczek 2010), it works in the field of sports competition for the most talented children.

The 400m run is a discipline combining both speed and endurance (anaerobic) capacities. In this case, both in the youngest and oldest age groups, the difficulty in covering that distance increases. The final result in covering one lap of the athletic stadium is mainly determined by exceptional (anaerobic) propensity that makes it possible to continue to run quickly under conditions of significant "acidification" of muscles (Letzelter 1979, Iskra 2015). The difficulty of

training and competition in the 400m run is evidenced by the fact that this distance was included in the Olympic women's contests only in 1984, i.e. more than 100 years after this discipline had been included in the men's contests. (Wallechinsky and Lucky 2012).

Age is of indisputable importance in defining the model of sports championship. Information concerning the age at which the sports abilities reach their peak, as well as the optimal time to begin an athlete's adventure and specialization in sports are essential in the selection of candidates for particular disciplines and events. Research based on those data can be used to draw practical conclusions, to forecast and evaluate the development of results and speed capabilities in human ontogenesis (Ważny and Sozański 1980; Sozański et al 1999, Tataruch 2014).

Knowledge concerning the change in sports performance level in relation to age provides an opportunity for the prediction of the period of peak performance in a given discipline. This enables proper planning of the training process. Rational training should be a step-by-step process, targeted and continuous, taking into account the personal changes in ontogenesis. Only such proceedings lead to the gradual development and maximization of training effects (Sachnowski 2002, Hohmann et al. 2002).

The accuracy of data presented by statisticians – members of the International Association of Athletics Federations (ATFS) - is helpful in assessing the age for the best results in track and field events. In Butler's extensive publications, one can evaluate the age at which the best results in all athletic events are achieved, by following various championship contests (Buttler 2012, 2015).

Table 1. Periods of sports success in track and field events (according to Płatonow 2004).

Events	First success		The highest performance		Maintaining high results	
	W	M	W	M	W	M
Sprint races	18-20	19-21	20-24	22-26	25-26	27-28

While assessing the importance of age in sports, the optimal age of sports championship is just the beginning of scientific observation. The data collected are the basis for the definition of a specific "sports ontogenesis", i.e. systematic changes in athletes' results and their sports development; in other words in the course of their sports careers defined as a specific curve of growth, stabilization and gradual reduction of sports performance level. The process of sports maturation is a specific stage of human ontogenesis, covering the period from the moment when interest is taken in a particular discipline, through the achievement of best results, to the end of the sports career (Skorowski 1968, Iskra 2005, Sozański et al. 2012).

The purpose of the study

The purpose of the study was to evaluate the development of results in men's 100 and 400m sprint races, taking into account the best results from the 6th to 100th year of age.

Material

The world's best sprinters (aged from 15 to 35) were subjected to detailed analysis. The sports ontogenesis of athletes achieving record-breaking results in the 100m race (9.86 ± 0.07 s) and 400m run (44.06 ± 0.32s) was analyzed. The record results were achieved within the period of 1968 to 2016. The data collected included the best results achieved by the respondents in the given calendar year - from the first to the last start in their sports careers. Additionally, the development of the best results in groups outside the championship competitions (up to the 14th and after the 35th year of age) was presented.

METHODS

While examining the development of the world's leading sprinters' careers, the authors took into account their best final results in each year of their starts. They were assigned to three research protocols that included age, successive years of starts, and periods before and after their personal best. This procedure was used in previous studies (Plewnia 2016, Dziadek 2017). The structure and method of data distribution are presented below:

Protocol 1 – analysis of achieved results taking into account the athlete's age.

Protocol 2 – analysis of achieved results in successive years of training.

Protocol 3 – analysis of achieved results before and after the personal best.

The results are presented taking into consideration arithmetic means and standard deviation (SD). In the comparative analysis of groups of runners over various distances (100 and 400m), the percentage value (%) of the result in relation to the world record over the given distance was chosen as a common element.

The other set of data includes results in all age groups - from the 6th to the 100th year of age. These data are available at www.age-records.125mb.com and www.world.masters.atchletics.com

Results

Looking for changes in the level of results with regard to the age, it is difficult not to refer to the record results achieved by the younger (children up to 14 years) and older (veterans aged over 35) representatives of age groups. Data from the age between 6 and 14 are supplementary to the analysis of sports championship development in the 100 and 400m runs. These results (especially concerning the longest sprint run) do not have much in common with the training methodology in this discipline, which applies to the older age groups (Smith 2005, Iskra 2015). They only inform about the possibilities of the human body at a given stage of ontogenesis. This is due to the lack of information about their later performance in the 400m run. The distance of 400 meters is extremely demanding and the runners have to be prepared for it in a balanced manner, taking into account the young athletes' age and above all their biological development. Premature specialization is not only inadvisable, but can be hazardous to health. Not without significance is the fact that the 400m run appears in the program of competitions only for younger juniors, i.e. young athletes aged under 15 (Butler 2015).

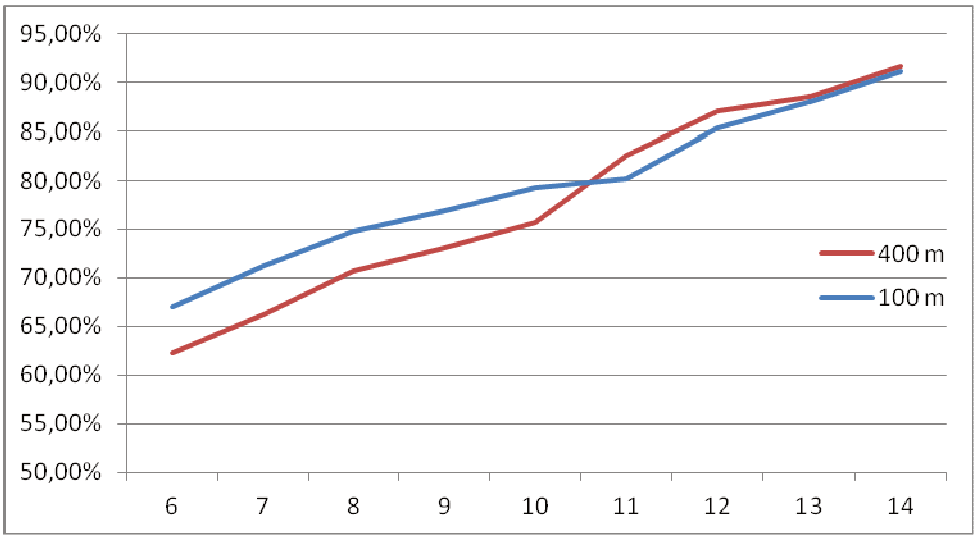

Fig. 1. Changes in running abilities over the distance of 100 and 400m in human ontogenesis up to the 14th year of age compared to the world record (WR=100%)

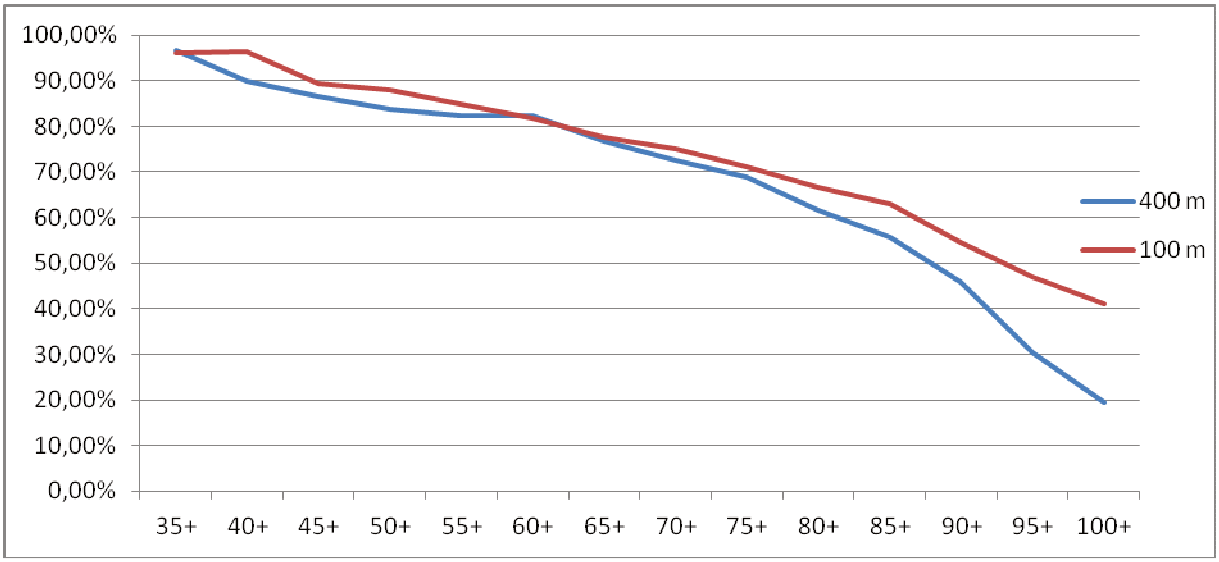

Fig. 2. Changes in running abilities over the distance of 100 and 400m in human ontogenesis after the 35th year of age compared to the world record (WR=100%).

Comparing the increase of results in the period up to the age of 30 with the decrease of sports skills level after the age of 35, almost symmetric relationships must be noticed (Figures 1. and 2.). Both an 11-year-old athlete and a 60-year-old one achieve about 80% of record results. The same can be noted for 6- and 80-year-old athletes (about 62% for 400m and 67% for 100m), 7- and 75-year-old ones (about 68%), 8- and 70-year-old ones (about 73%) as well as 9- and 65-year-old ones (about 77% of the world record). In human ontogenesis, the scale (magnitude) of speed abilities' development up to the age of 14 is similar to the regression scale after the 35th year of age. Figures 1. and 2. also indicate the difference in results regarding distances 100m and 400m at the very early (up to 10 years) and very late (after 75 years) life stages. From the data it follows that the speed and endurance capabilities appear later and decrease relatively early.

An analysis of sports career development of the 50 best sprinters in the history of the 100m race showed that the mean value of the best results achieved by the above mentioned athletes throughout the course of their careers is 9.86 ± 0.07 sec., with a minimum result of 9.58 sec. and a maximum one of 9.93 sec., and concerns the 25th year of age (± 3 years). The age at which the personal best is achieved varies within the wide range between the 20th and 33rd year of athletes' age. In the shortest sprint race, the number of analyzed data (n = 42) increases up to the age of 22, then it remains at a relatively constant level (n = 38-40) within the age from 23 to 25; after that the number of analyzed data constantly decreases. (in the 31st year of the examined sprinters' age n <200).

The analysis of sports' career development of the 50 best sprinters in the history of the 400m run showed that the mean value of the best results achieved by the above mentioned athletes throughout the course of their careers is 44.06 ± 0.32 sec., with the minimum result of 43.03 sec. and the maximum one of 44,36 sec. and concerns the 24th year of age (± 3 years). The age at which the personal best is achieved varies over a wide range between the 18th and 32nd year of the athletes' age.

By studying the sports championship development based on the results achieved in the given year of age of the world's best 400m runners, it can be noted that up to the 23rd year of age the number of analyzed data increases (n = 34). From the age of 24 to 26 on, it remains at a constant level (n = 27), and later on the number of analyzed runs decreases.

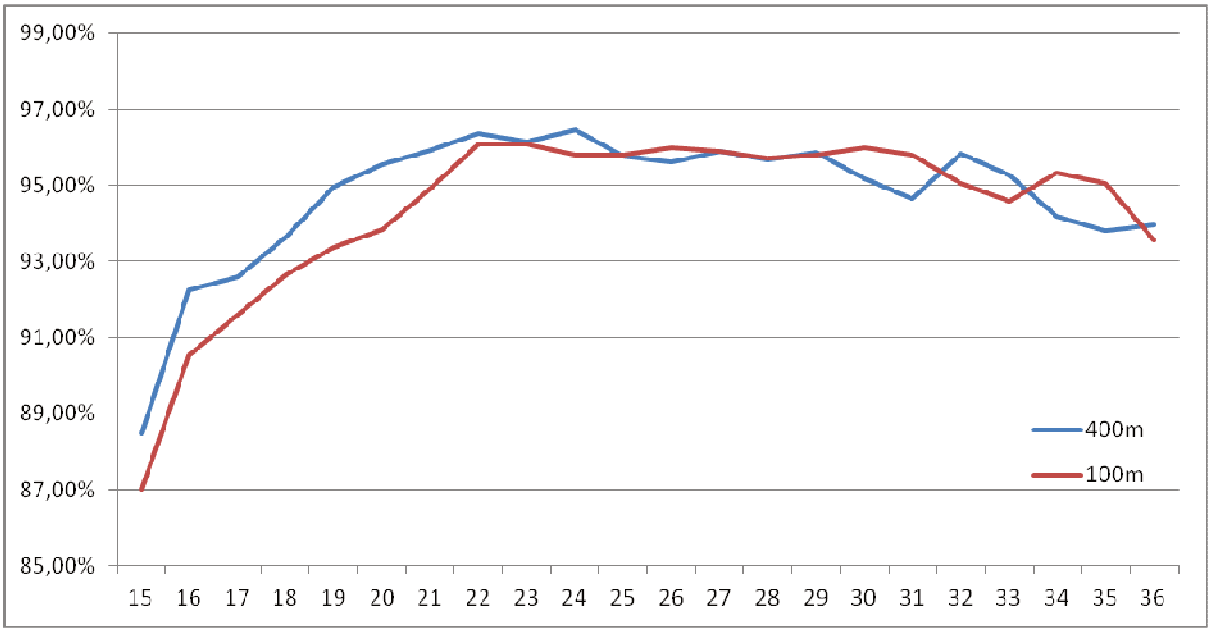

Fig. 3. Sports championship development in men's 100m and 400m run, taking into account the athletes' age in relation to the world record in particular discipline (WR=100%)

By studying the sports championship development based on the results achieved in the following year of age of the world's best 400m runners, it can be noted that the most dynamic results progression of the researched groups takes place up to the age of 22; after that, in the group of 400m runners it stabilizes up to the age of 29 at a relatively equal level (Fig.3.). This may indicate that the age from 20 to 29 is the best period in which the athletes running over the longest sprint distance can achieve record results. On mean, the fastest short distance sprinters maintain the highest level of sports championship up to the 31st year of age. After the 32nd year of age, the level of results regresses systematically in both examined groups of athletes.

Table 2. Significance of differences between the sports performance level at particular stages of sports championship.

Stage (years of career)	100m			400m		
	n	x- SD (s)	ANOVA	n	x-SD (s)	ANOVA
17	12	10,46 ± 0,09	0,05	7	46,29 ± 1,06	-
18	20	10,34 ± 0,16	-	13	45,76 ± 1,38	-
19	34	10,26 ± 0,16	-	20	45,37 ± 0,95	-
20	37	10,21 ± 0,22	0,01	22	45,09 ± 0,83	-
21	41	10,09 ± 0,17	0,01	27	44,76 ± 0,78	-
22	42	9,97 ± 0,21	-	31	44,63 ± 0,74	-
23	39	9,98 ± 0,15	-	34	44,76 ± 0,93	-
24	40	10,01 ± 0,18	-	31	44,59 ± 0,64	0,05
25	38	10,01 ± 0,14	-	26	44,96 ± 0,61	-
26	35	9,98 ± 0,15	-	27	45,02 ± 1,02	-

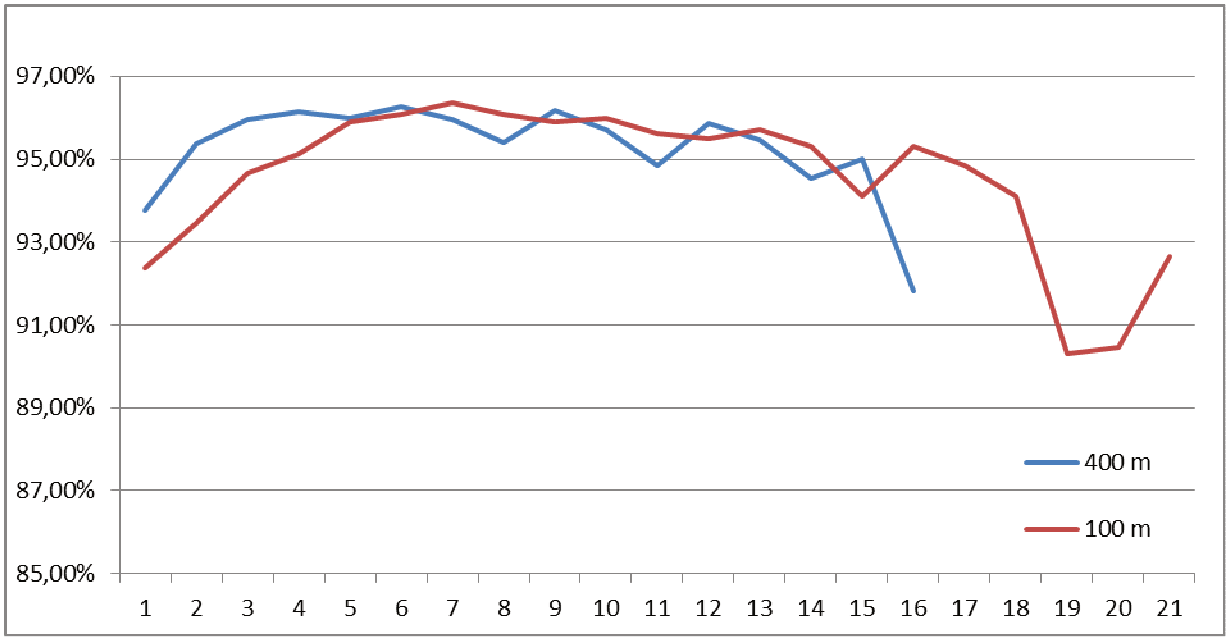

Fig. 4. Sports championship development of the best sprinters in the history of 100m and 400m runs in the consecutive years of their careers in relation to the world record (WR=100%)

The analysis of the consecutive years of the best sprinters' careers indicates that the most dynamic development of results takes place in the first four years of specialized training in the group of 400m runners (from the mean result of 45.89 ± 1.45 sec., for n = 50 on up to 44.75 ± 0.70 sec. (n = 35) and in the first seven years for 100m sprinters (from 10.37 ± 0.21 sec. on up to 9.95 ± 0.12 sec., respectively). After eight years of continuous 100m sprinters' career, there is a mild but steady decrease in the results' level (from 9.97 to 10,17 sec.). In the fifth year of the 400-m runners' career, the sports performance stabilizes at a similar level for another three years. In the later years of the fastest male 400m runners' career, the mean values of the results decrease and increase alternately and the sports performance level shows a general declining trend.

Table 3. The significance of differences between the sports performance level at particular stages of sports championship in the consecutive years of examined athletes' careers.

Stage (years of careers)	100m			400m		
	n	x- SD (s)	ANOVA	n	x-SD (s)	ANOVA
1	50	10,37 ± 0,21	0,01	50	45,81 ± 1,29	0,01
2	45	10,26 ± 0,21	0,01	38	45,15 ± 0,92	0,01
3	42	10,11 ± 0,15	-	39	44,80 ± 0,57	-
4	47	10,06 ± 0,14	0,05	36	44,70 ± 0,64	-
5	42	9,99 ± 0,13	-	37	44,70 ± 0,81	-
6	47	9,97 ± 0,12	-	31	44,70 ± 0,72	-
7	43	9,95 ± 0,24	-	26	44,76 ± 0,74	-

The analysis of the consecutive years of the examined sprinters' careers indicates that the continuous progress within the first three years of participating in sports competitions, i.e. between the first and the third year of sports career development is statistically significant (p≤0,01). In addition, among sprinters specializing in the distance of 100m, the period between the fourth and fifth year of runners' sports career development has an impact at the level of p≤0.05.

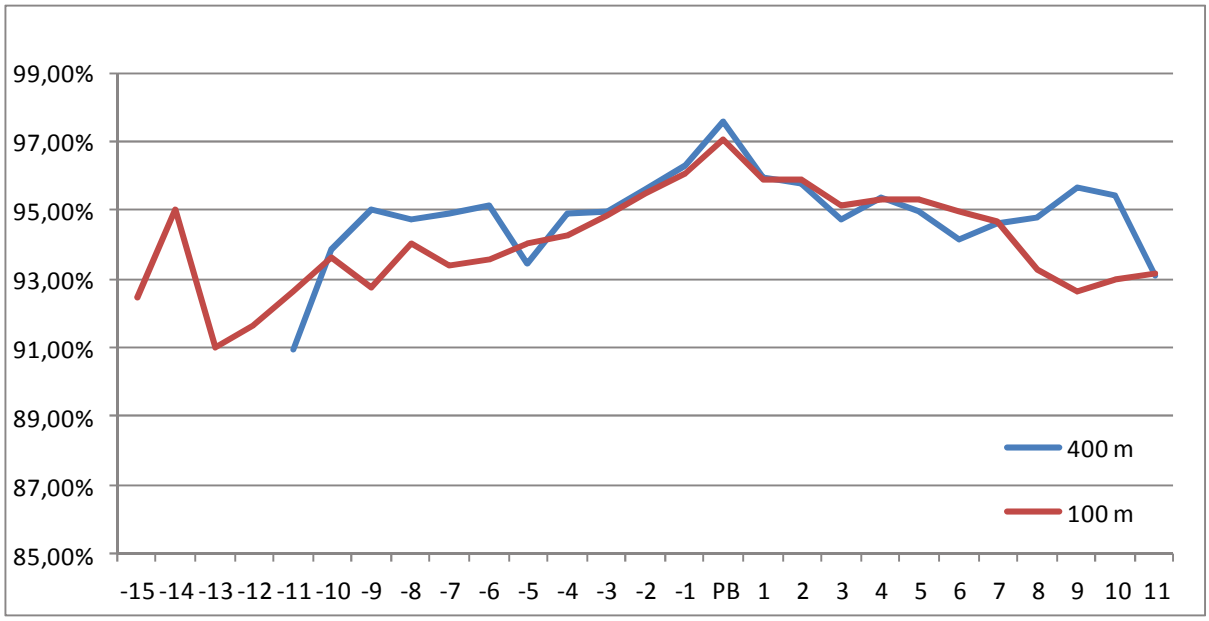

Fig. 5. Sports championship development of the best sprinters in the history of 100m and 400m runs in the previous and following years since achieving the best results in their careers in relation to the world record (WR=100%)

The research results indicate that continuous progression of results concerns the period of five years prior to the personal best ("PB") achieved by the fastest 400m runners and eight years prior to achieving the "PB" by the fastest 100m racers in the history of those events. The permanent regression of results after achieving the "PB" concerns the following three years of careers in both groups of examined sprinters. In the 4th year after the 400m runners discussed achieved their "PB" and in the 4th and 5th year after achieving the best result in the career in the group of 100m sprinters, the mean result improves. This affects the general regression of the results following the establishment of the personal best of the examined athletes.

In analyzing the influence of the years before and after achieving the best results in the careers of examined sprinters, it should be noted that the two years preceding the achievement of the best results in their sports careers have statistically significant impact (p≤0.01) on the runners themselves and their achievement of their "PB" in both groups of runners specializing in distances of 100 and 400m. In addition, the 3rd year before achieving the best result in the careers of examined athletes among the tested 400m runners has a significant impact (p≤0.05) on the runners themselves and the achievement of their "PB".

Table 4. The significance of differences between sports performance levels at particular stages of sports championships in the years before and after achievement of PB amongst the athletes examined.

Stage (years of career)	100m			400m		
	n	x- SD (s)	ANOVA	n	x-SD (s)	ANOVA
-4	40	10,14 ± 0,19	-	21	45,40 ± 1,06	-
-3	41	10,09 ± 0,19	-	29	45,27 ± 0,89	-
-2	46	10,02 ± 0,12	-	31	45,08 ± 0,83	0,05
-1	45	9,95 ± 0,20	0,01	38	44,68 ± 0,61	0,01
PB	50	9,86 ± 0,07	0,01	50	44,06 ± 0,32	0.01
1	37	9,98 ± 0,11	-	37	44,87 ± 0,83	-
2	34	9,99 ± 0,12	-	21	44,85 ± 0,66	0,05
3	34	10,06 ± 0,20	-	17	45,34 ± 0,73	-
4	24	10,05 ± 0,13	-	13	45,02 ± 0,65	-
5	24	10,04 ± 0,10	-	13	45,27 ± 1,02	-

Table 5. Correlation coefficient between the selected parameters and personal best of examined sprinters.

Parameter	**100m**		**400m**	
	r	**p**	**r**	**p**
17th year of age (cadet)	0,48	-	-0,13	-
19th year of age (junior)	-0,13	-	0,35	-
22nd year of age *	0,46	0,01	0,36	0,05
23rd year of age * (youth)	0,65	0,01	0,39	0,05
1st year of career	0,07	-	0,13	-
2nd year of career	0,16	-	0,20	-
5th year of career*	0,56	0,01	0,47	0,01
6th year of career*	0,52	0,01	0,53	0,01
3 years prior to "PB"*	0,46	0,01	0,51	0,01
2 years prior to "PB"*	0,51	0,01	0,63	0,01
1 year prior to "PB"*	0,63	0,01	0,78	0,01
1 year after achieving "PB"*	0,65	0,01	-	-
2 years after achieving "PB"*	0,59	0,01	-	-
3 years after achieving "PB"*	0,49	0,01	-	-

*The statistically significant selected parameters correlating with "PB" of examined sprinters (p≤0.05)

The statistically significant (p≤0.05) results of 400m runners in the periods from the 22nd to the 26th and from the 28th to the 32nd years of age, except for the 30th year of age, correlate with their personal best (PB). In the 24th and 28th years of age, the value of p≤0.01 achieved statistical significance. The statistically significant (p≤0.01) mean values of results achieved by the world's fastest 100m sprinters between their 22nd and 31st year of age correlate with the best results in their sports careers. This confirms the fact that it is the best time to achieve results at

the highest world level. Results in the 24th and 28th years of age correlate statistically with the PB at the level of $p \leq 0.05$. The conducted analysis of results in relation to the age of examined sprinters did not show any statistically significant impact of the age of cadet (U18) and junior (U20) on their results in relation to their later record achievements (Table 5).

Studying the correlation between the results achieved by the best sprinters in the consecutive years of their careers in both groups (100 and 400m), there was a statistically significant relation with the best results in the period from the 5th to the 12th year of sports career development ($p \leq 0.01$). It is to be noted that in both groups of sprinters, the results achieved by them in the first two years of their careers do not have a statistical impact on the later record results at world level.

All mean results from the period of three years prior to achieving the best results in their career by world-class athletes are statistically significant with their PB (Table 4, $p < 0.01$). In addition, in the group of examined 100m runners, the results from years 1-4 following the establishment of their "PB" correlate significantly with the best results in their careers ($p \leq 0.01$).

Discussion

Research on human motor abilities in the context of sports ontogenesis indicates that the peak of speed development as a motor ability is achieved within the age range from 20 to 23, while the peak of endurance and strength development is observed between the 24th and 27th year of age (Krawiec 1989).

In the 1980s, it was a common view that athletic training should be taken up as early as possible. The research of Iskra (2005) showed that the beginning of training and sports specialization too early does not guarantee achievement of becoming a sports champion. Sozański et al. (1993) believe that the late engagement of a child in sports activities is better than taking them up too early.

The high sports performance level of young champions is first of all the result of specialized training already performed in the youngest periods of age. Those athletes who make further progress have usually trained in a different manner based on a comprehensive and targeted preparation (Sozański 2003). Youth sport cannot be aimed at maximizing the performance already in the youngest age groups. Adolescent athletes exploited too early are unable to make further progress; they often suffer from injuries, and eventually give up their training. For years there have also been characteristic constant age ranges, in which the percentage results rates of stagnation frequencies and the giving up of sports activities are the highest, also including track and field runs. At the age of 19-21, this indicator concerns almost 65% of women and 52% of men (Sozański 2013).

The comprehensive analysis of age dynamics (Sachnowski and Iskra 2015), in which the best results in athletics and swimming are achieved, indicates that after a significant increase in the 1980s and 1990s of the age at which championship results were achieved, at the beginning of the 21st century a trend to stabilize this was observed.

This phenomenon can be explained by the commercialization and professionalism of Olympic sports. In the last few decades, along with the extension of sports championship formation, the length of its maintenance has increased even more. According to Płatonow (2004) and Szustin (2001), the above mentioned elements significantly contributed to the prolongation of sports ontogenesis in the context of competition at the highest level.

Until now, the best age to take up the adventure with sport in sprint disciplines was considered to be from 10 to 12 years. The age range from 14 to 16 was considered ideal for beginning a specialization. The age at which record results are achieved ranges from 22 to 26 years (Bompa and Haff 2010). At the same time, according to the data provided by Vaeyens et al. (2009), only less than half (44%) athletes participating in the Olympic Games in Athens in 2004 took part in international junior contests in their sport discipline. Most of them (56%) had such debuts only at senior age. Of the 387 athletes competing in the 28th Olympic Games track and field events, 8% of them began their adventure with sports before the age of 8, 10% within the range of 9-10 years, 17% at the age

from 11 to12, 22% started training at the age of 13-14 and 43% were more than 15 years old.

According to Kampmiller (2000), the optimal age for maximizing athletic performance in the men's 100m race is the age range from 20 to 25. In the men's 400m run, this range is extended and shifted and ranges from 22 to 28 years.

The results of various studies inspired the research team to reflections and analysis of sports career development of the best athletes specializing in the shortest and the longest sprint race (100 and 400m). The analysis of results showed that the greatest dynamics of results development in both groups occurs up to the age of 22 and in the first four years, taking into account the successive years of the 400m runners' sports career and the first seven years for the world's fastest "short" sprinters. The mean value of the 400m runners' results assigned to the athlete's age at the time of their achievement indicates that the best time for the distance of one lap of the athletic stadium is achieved aged 20 to 29. This is confirmed by previous analyses (Płatonow 2015). At this age, the mean of results is less than 45 seconds.

The fastest sprinters specializing in the 100m race maintain the highest sports championship level on average up to the age of 31. The mean of the fastest sprinters' results is equal to or less than 10 seconds and occurs at the age between 22 and 31. This may indicate that this period is the best time to continue the sports career running over the shortest sprint distance. In this period, the mean of results is also statistically significant ($p \leq 0.01$) and correlate with the best results in their sports careers.

The best time for men to start the competition over the distance of 400m is the age from 18-20. After four years of the most dynamic sports career development the age of 24 is the mean (± 3 years) age for achieving the best result in the career of a 400m runner. Track and field athletes can continue their struggles over the distance of one lap of the athletic stadium at the world's level until the age of 29. According to the research, after this time there is a regression in sports results. Considering the mean age of achieving the best records in the careers of the world's 50 best 100m sprinters, and taking into account that the period during which these athletes achieve their personal best is 7 years, and that the constant progression of results is shaped within the first 8 years of sports career, the best time to begin the specialization at the shortest sprint distance is the age of 17-18.

The conducted analysis of results assigned to the age of examined sprinters did not show any statistically significant impact of cadet's (U18) and junior's (U20) age on their results in relation to their later record achievements, which confirms the assumption that beginning training and sports specialization too early does not guarantee the achievement of becoming a sports champion (Iskra 2005).

The research into the correlation between the results achieved by the best sprinters in the history of the two race categories showed that the mean results achieved within the period ranging from the 5th to 12th year of their careers in both groups have a statistically significant impact on athletes' personal best. The mean results from the period of three years before achieving the best result in the careers of athletes at world level in both groups are also statistically significant with their "PB". Additionally, in the group of examined 100m runners, the results achieved during the period of 1-4 years after achieving the "PB" correlate significantly with the best results in their careers. The above statements may be important in organizing the training process at various stages of sports championship.

Conclusions

1. In the 100m race (at the level of 9.86 ± 0.07 sec.), the mean age of achieving record-breaking results is 25 ± 3 years. The mean age of achieving the best results in 400m run (results level: 44.06 ± 0.32 s) is 24 ± 3 years.

2. The greatest dynamics of change (progress) of results in both sprints occurs up to the age of 22. In the 100m race, this concerns the first seven years of a sports career, and in the 400m run, the first four years of specialized training.

3. The best sprinters' results (under 10 seconds) are achieved within the period from the 22nd to the 31st year of age. The mean of results in this period significantly ($p \leq 0.01$)

correlate with the best results in their sports careers.

4. In the 400m race, the age from 20 to 29 is the best time to continue the sports career over this distance at the highest world level. In this period, the mean of results is less than 45 seconds.

5. In both examined groups, the periods of three years prior to achieving the best results, and 4 years after that is the time in which the maximum results in sprints are achieved.

6. Of statistically significant importance ($p \leq 0.01$), in the context of record results, are the first three years of starting in running contests and two years prior to achieving the "PB".

7. The development of speed abilities up to the age of 14 is similar to the scale of their regression after the age of 35. An 11-year-old athlete and a 60-year-old one achieve about 80% of their record results. The same can be noted in the case of 6- and 80-year-old athletes (about 65%), 7- and 75-year-old ones (about 68%), 8- and 70-year-old ones (about 73%) and 9- and 65-year old ones (about 77% of the world record).

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