THE IMPORTANCE OF REACTION TIME IN ATHLETICS: INFLUENCE ON THE RESULTS OF SPRINT RUNS OF WORLD CHAMPIONSHIPS FINALISTS

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Abstract In athletic sprint disciplines, the segments of start and start acceleration occupy an important place that significantly generates the final outcome of the race. The question is to what extent the start time of the reaction (latent time) has a contribution to achieving the results of sprint disciplines. The aim of the current research was to determine the influence and connection between the reaction time and the result performance of running in the disciplines of 100 m, 200 m, 400 m finalists of ten world championships. The results of a total of 456 finalists (231 men) and 225 (women) competitors who competed in the final races of the championships (from Edmonton, 2001 to Doha, 2019) were analyzed. The evaluation of the start reaction time and sprint results was based on reports officially published by the International Association of Athletics Federation (IAAF). Central and dispersion parameters were calculated for all variables. The relationship between reaction time and sprint results was calculated using the Pearson correlation coefficient, and simple regression analysis determined the direct influence of reaction time on the result success and calculated the relevant coefficients for the level of statistical significance $p < 0.05$. Based on the obtained results, a positive but low correlation was recorded between the mean values of the 100 m sprint results and the reaction time in men ($r = 0.230^{p<0.044}$), which was also confirmed by regression analysis. In other correlations and values of regression coefficients, no significant numerical values of the influence of reaction time on the result success were recorded in both categories of finalists.

Key words elite athletics, IAAF, sprint disciplines, performance, reaction time

Introduction

Athletic sprint disciplines are one of the segments within the athletic competitions that attract a lot of attention, both from the spectators and from the athletes themselves and their coaches. The results achieved in these disciplines are exact and manifest the maximum individual capabilities of individuals in terms of technical, tactical and motor-physiological potentials. The technique and tactics of the sprinter are manifested in all segments of running on the track and they depend on the length of the track, i.e. whether it is 60 m, 100 m, 200 m or 400 m. Also, the motor-physiological potentials occupy a significant place, manifesting themselves during the start, starting acceleration, running on the track and finish. They are also highly correlated with path length. One of these motor-physiological parameters is the motor reaction time (so-called latent time), which is very important in sprint disciplines.

Motor reaction time is defined as the time between the detection of sensory-motor stimulation and the behavior of the athlete's body afterwards (Spierer, Petersen, Duffy, Corcoran, Rawls-Martin, 2010). Collet (1999) defines reaction time as the time from the gun signal (firing) to the moment when the athlete produces force on the starting blocks (imprinting), which includes the travel time of sound between the sound source and the athlete, the athlete's reaction to sound and mechanical activation of false start equipment integrated into the starting block (Tønnessen, Haugen, Shalfawi, 2013). According to the competition rules of the International Association of Athletics Federations (IAAF), a reaction time of less than 100 ms is considered a false start. It is a very important determinant of the success of sprint runs, where hundredths of a second often decided about for medals, so a bad start (long reaction time) is often one of the factors that can be a disruptive factor in the overall ranking. The fastest starting reaction time (RT) in the sprint was recorded by Tim Montgomery (0.104 s) back in 2002. The time from the sound signal of the starting pistol to the beginning of the muscle contraction, although limited by athletic rules, remains in the domain of the researcher, due to the fact that each sprinter tries to achieve the shortest start reaction time, thus a better result at the end of the race (Juhas, Matić, Janković, 2015).

Previous research shows that start and start acceleration have a significant share in achieving maximum results in sprint disciplines. According to the available information (Čoh, 2001), the length of the initial acceleration depends on the morpho-motor potentials, the anaerobic-lactate system and the intensity of the sprinter CNS excitation. In the first ten meters, sprinters develop up to 55% of their maximum speed, up to twenty meters (70–80%), and up to thirty meters (85–95%). Between 50m and 80m sprinters reach the maximum speed (more than 11.5m/s), and after 80-90m the achieved speed decreases. The drop in speed at the finish of the race is a consequence of lower speed endurance, i.e. weaker anaerobic capacity of sprinters. However, there is an exception here for some high-class sprinters. For example, Usain Bolt achieved a *World Record of 9.58 seconds* in the final of the World Championships in Berlin in 2009, and reached a maximum speed of 12.35 m/s at 70 meters. At the London Olympics in 2012, he achieved 9.63 sec, and reached a maximum speed of 12.42 m/s at 80 meters (Pavlović, 2014), which is a kind of confirmation that high-class sprinters have excellent and fast endurance. These are mostly top sprinters with exceptional results, who base their path to success on the good realization of this factor. With a good realization, they try to gain a certain advantage in the first meters after the shot, which they try to keep until the end of the race (Tønnessen et al., 2013). Often in large competitions (Olympic Games, World and European Championships, Diamond Leagues), certain differences are observed in terms of the time of the initial reaction between disciplines (Pavlović, Raković, Idrizović, Mihajlović, 2013; Pavlović, 2015) and depending on gender (Juhas, Matić, Janković, 2015; Pavlović, Idizović, Vrcić, Mosurović, 2014). However, these differences are sometimes not large, so it often happens that 100 m sprinters achieve a reaction time almost identical to the reaction time at 400 m or that there are no significant differences between the reaction time (100 m, 200 m or 400 m), although there are some differences in track length (Pavlović, 2015; Pavlović, Bonacin, Bonacin, 2014). These findings contradict the fact that the importance of starting acceleration and reaction time is more important in shorter (Téllez, Doolittle, 1984; Moravec, Ruzicka, Susanka, Dostal, Kodejs, Nozek, 1987; Gürses, Kamiş, 2018) than in longer sprint disciplines. This leads us to the conclusion that these are top athletes who engage their psychophysical capacities to the maximum, regardless of the length of the track. Precisely because of these facts, it is no coincidence that many authors enter into a biomechanical analysis of these two phases to explain the phenomenon of sprinting speed and starting acceleration, which are based on the start reaction time (Guissard, Duchateau, Hainaut, 1992; McClements, Sanders, Gander, 1996; Harland, Steele, 1997; Čoh, Peharec, Bačić, 2007; Bračić, Peharec, Bačić, Čoh, 2010; Pilianidis, Mantzouranis, Kasabalis, 2012). The coach of the famous sprinter Carl Lewis, Tom Tellez (1986), in his study came to the conclusion that the result of 100 m is influenced by the reaction time (1%), the speed of leaving the starting blocks (5%), starting acceleration (64%), the ability to maintain maximum speed (18%), 12% and less speed drop at the finish (Pavlović, 2014). Research conducted by some authors (Babić, Čoh, 2010; Harland, Steele, 1997; Wang, 2006; Pain, Hibbs, 2007; Babić, 2008) agrees that the result in the sprint depends on the position in the starting block, i.e. positions of the center of gravity of the body, the time of the initial reaction and the initial acceleration.

Initial acceleration is a complex cyclic movement defined by the progression of the frequency and length of the steps, the duration of the contact and flight phases, the position of the center of gravity at the moment of contact with the ground, propulsion in the flight phase and the forces overcome in the first step (Hunter, Marshall, McNair, 2005). All these parameters are conditioned by the functioning of the CNS, motor abilities, energy processes, morphological characteristics and muscle structure (Locatelli, Arsac, 1995; Young, McLean, Ardagna, 1995; Muller, Hommel, 1997; Čoh, Tomažin, Štuhec, 2006; Mero, Kuitunen, Harland, Kyrolainen, Komi, 2006) and have been widely examined in the literature in different populations and different contexts (Spierer, Petersen, Duffy, Corcoran, Rawls-Martin, 2010; Salonikidis, Zafeiridis, 2008; Wang, 2009), Babić, Delalija, 2009; Spierer, Petersen, Duffy, 2011).

Certain research (Moravec, Ruzicka, Susanka, Dostal, Kodejs, Nozek, 1988) proves that certain characteristics of sprinters and reaction time are extremely good predictors of results in sprints. Also Martin and Buonchristiani (1995), believe that for the final result in the sprint (100 m and 200 m) the length of acceleration, the achieved maximum speed and speed endurance are more important (Pavlović, 2014; Moravec et al. 1988). Smajlović and Kozić (2006) believe that the effects of changes in athletic rules also contributed to changes in the start reaction time. They determined the effects of changing athletic rules on the start reaction time in sprint disciplines. A sample of top athletes from the World Championships in Edmonton 2001 and Paris 2003 obtained results that confirmed the differences in the starting time of the reaction between these two World Championships in the disciplines, 100 m, 200 m, 110 m and 100 m hurdles for men and women, while the differences by gender have not been determined. Research by some authors (Tønnessen et al., 2013; Pavlović, Raković, Idrizović, Mihajlović, 2013; Gürses, Kamiş, 2018; Haugen, Shalfawi, Tønnessen, 2012; Pilianidis, Kasabalis, Mantzouranis, Mavvidis, 2012) is based on the study of these parameters from the aspect of sprint disciplines where they try to analyze the start reaction time and running results in major competitions, such as World, European Championships and the Olympic Games.

Precisely because of the numerous advantages and relevance of starting acceleration in the prediction of athletic sprint disciplines, which is based on the start reaction time, this research was conceived. The main goal of the research is to determine the influence and possible connection between the reaction time (latent time) with the results in sprint disciplines at the World Championships from 2001 to 2019.

Material and methods

Participants

The research originally included 487 competitors (244 male and 243 female sprinters) participants in the finals at the World Championships from 2001 (WCh Edmonton) to 2019 (WCh Doha) in the disciplines 100 m, 200 m, 400 m. Out of the total number of finalists, 31 competitors (13 male and 18 female) were not included in the study and analysis of the results (based on DQ, DNF, DNS). The study included 456 competitors (231 male and 225 female) who competed in the World Cup finals. Their achieved results and reaction time in sprint disciplines were analyzed. The results are taken from the official IAAF website (www.worldathletics.org/competitions/world-athletics-chaptemps/history).

Design and statistical analysis

For the purposes of this research, the start time of the reaction was defined as an independent variable (predictors), while the results of running 100 m, 200 m, 400 m were defined as dependent variables (criteria). First, the central and dispersion parameters (Mean, SD, Min., Max, Range, CV%) were calculated for all variables, while the Pearson correlation coefficient was used to determine the relationship between reaction time (RT) and the results of sprint disciplines. The level of acceptance of statistical significance was set to $p < 0.05$. The obtained correlations are presented in tables and graphs. In order to more accurately confirm the results defined by the research goal and to determine the influence of reaction time on the result performance, a univariate model of regression analysis was applied, and the relevant coefficients were calculated. The statistical package STATISTICA, version 10.0 (STA999k347150-W) was used for data processing.

Results

Table 1 contains the numerical central and dispatch parameters of the male and female finalists of the World Cup participants. Correlations between predictors and criteria for both subsamples in the analyzed disciplines were calculated. As might be expected, male finalists achieved a better average result in all sprint disciplines of the world championships: 100 m (10.05 ±0.16 sec.), 200 m (20.24 ±0.75 sec.), 400 m (44.75 ±0.58 sec.) In relation to the female finalists 100m (10.99 ±0.16 sec.), 200 m (22.55 ±0.37 sec.), 400 m (50.25 ±1.07 sec.). Identical conclusions also apply to the average results of the achieved start reaction times in all sprint disciplines, as follows, 100 m (150.95 ±18.91 ms male and 160.64 ±30.34 ms female), 200 m (155.37 ±16, 49 ms male and 171.83 ±22.62 ms female), 400 m (177.91 ±38.07 ms male and 196.30 ±49.53 ms female). However, in the case of minimum and maximum results of the initial reaction, there are significant oscillations, both by discipline and by gender, which also show the numerical values of these results. In terms of homogeneity of results (CV%), men recorded the highest homogeneity in running 400 m (CV = 1.29%) and the lowest in 200 m (CV = 3.71%). Compared to the male finalists, women were the most homogeneous in the 200 m discipline (CV = 1.64%) and blurred in the 400 m discipline (CV = 2.12%). In terms of start reaction time, both finalist subsamples had the highest homogeneity in the 200 m discipline, while the average heterogeneity was most pronounced in the 100 m and 400 m disciplines.

Table 1. Descriptive statistics World Championship (Edmonton, 2001; Doha, 2019)

Sprint disciplines		Mean±SD (min.-max.)	Range	CV%	Symple regression analysis			
					R	R²	F	p < 0.05
100 m (♂) n = 76	Rt (ms)	150.95 ±18.91 (112–224)	112	12.53	0.230	0.053	4.195	0.044*
	Results (sec)	10.05 ±0.16 (9.58–10.95)	1.37	1.65				
200 m (♂) n = 79	Rt (ms)	155.37 ±16.49 (117–198)	81	10.48	0.047	0.002	0.173	0.678
	Result (sec)	20.24 ±0.75 (19.19–26.27)	7.08	3.71				
400 m (♂) n = 76	Rt (ms)	177.91 ±38.07 (127–350)	223	21.40	–0.010	0.000	0.007	0.930
	Result (sec)	44.75 ±0.58 (43.45–46.23)	2.78	1.29				
100 m (♀) n = 75	Rt (ms)	160.64 ±30.34 (113–290)	177	18.88	0.045	0.002	0.146	0.704
	Results (sec)	10.99 ±0.16 (10.09–11.33)	1.24	1.79				
200 m (♀) n = 75	Rt (ms)	171. 83 ±22.62 (136–239)	103	13.16	0.097	0.009	0.699	0.406
	Result (sec)	22.55 ±0.37 (21.63–23.17)	1.54	1.64				
400 m (♀) n = 75	Rt (ms)	196.30 ±49.53 (107–352)	245	25.23	–0.102	0.010	0.761	0.386
	Result (sec)	50.25 ±1.07 (44.18–52.89)	8.71	2.12				

Note: ♂ male; ♀female, * p < 0.05.

The correlation between the defined criteria (sprint disciplines) and the predictor (reaction time) was calculated using the Pearson correlation for the significance level ($p < 0.05$). The correlations presented in the table and graphically recorded almost insignificant numerical values between the start reaction time and the achieved result of sprint disciplines (100 m and 200 m) in both subsamples, while in the 400 m discipline this correlation also recorded negative numerical values. Out of a total of 6 corresponding pairs (disciplines) that were tested, a significant correlation was achieved between the start reaction time and the results in the 100 m male finalists for the level ($0.230^{p=0.044}$) (Table 1, Figure 1). There was no significant association in the other disciplines (Figure 2–6). Also, the applied regression analysis in sprint disciplines (Table 1) indicates a statistically significant effect of reaction time on the result performance of 100 m in men, where the coefficient is low but acceptable ($R = 0.230$) with the coefficient of determination ($R^2 = 0.053$), where $F = 4.195$ for significance level $p = 0.044$. In the remaining five disciplines (100 m women, 200 m and 400 m men and women) the reaction time did not prove to be a significant predictor in the result placement.

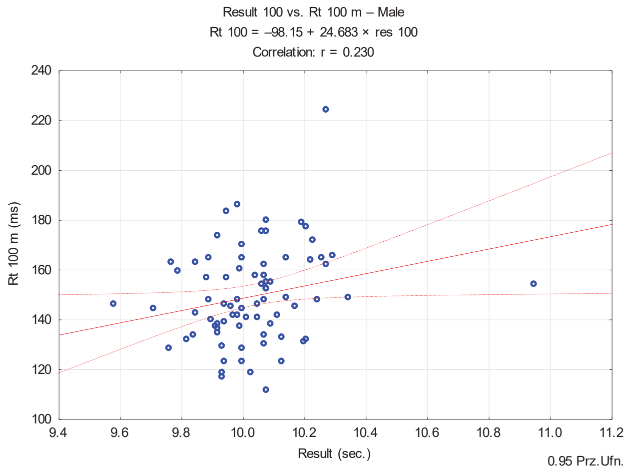

Figure 1. Correlations of male finalists (run 100 m)

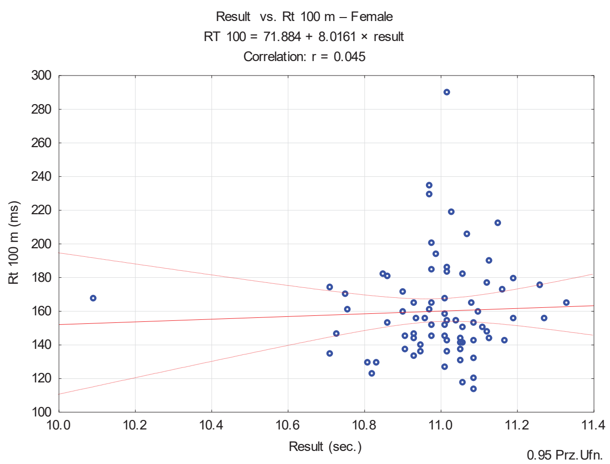

Figure 2. Correlations of female finalists (run 100 m)

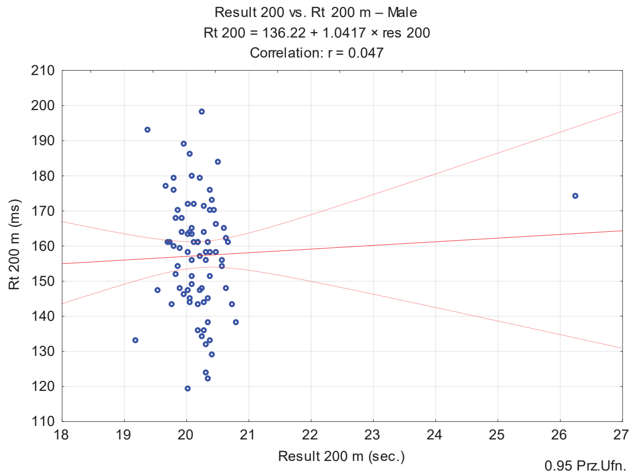

Figure 3. Correlations of male finalists (run 200 m)

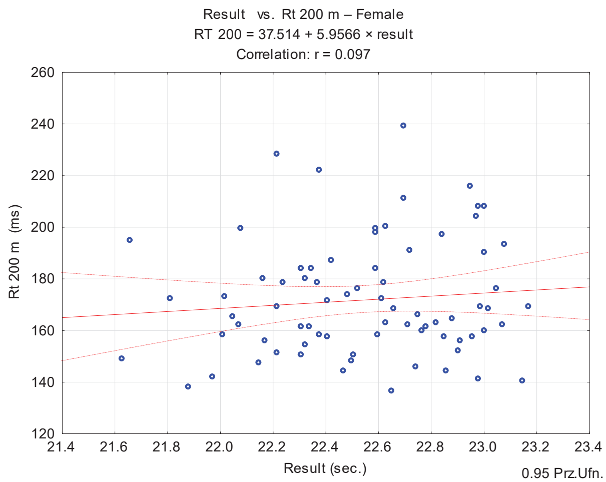

Figure 4. Correlations of female finalists (run 200 m)

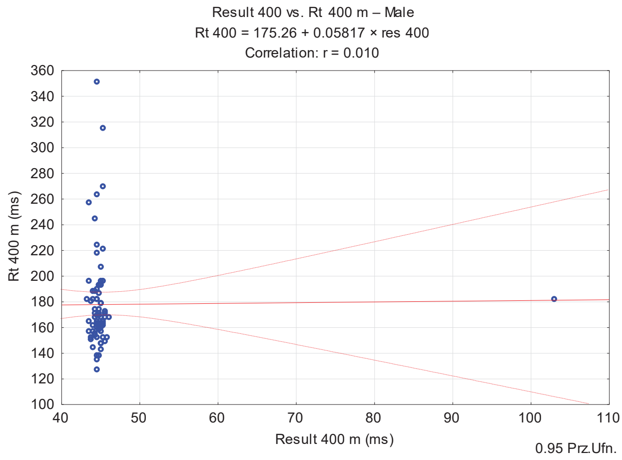

Figure 5. Correlations of male finalists (run 400 m)

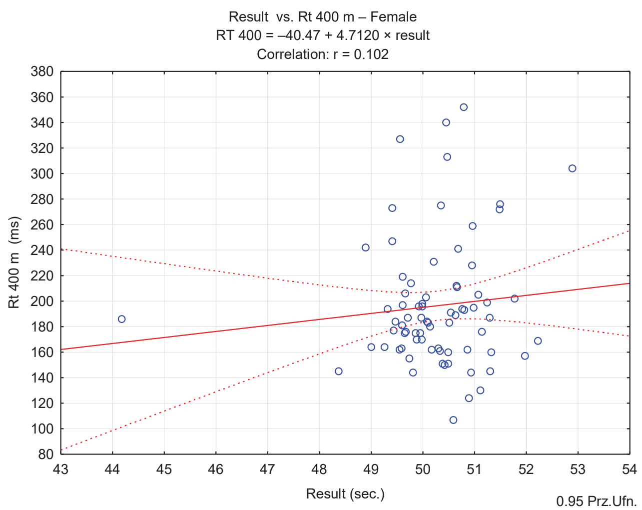

Figure 6. Correlations of female finalists (run 400 m)

Discussion

The top performance of sprinters is the result of the integration of several factors (genetic potential, training, health condition of the athlete, etc.). In athletics, the time of the (starting) reaction is becoming more and more important in the result performance of sprint disciplines

From an anthropological point of view, rection time is the body's ability to respond quickly to environmental stimuli (a shot from a starting pistol). Higher reaction speed also gives shorter reaction time, which is only one of several factors that influence the result success in modern athletics (Pain, Hibbs, 2007).

The current study was conducted on a sample of 456 elite male and female finalists of ten world championships in sprint disciplines with the aim of determining the impact and correlation of reaction time with the achieved results. By applying adequate statistical procedures, the obtained results confirmed a statistically significant influence and correlation between the reaction time and the achieved result in running 100 m, in male athletes with a result of low numerical value (Table 1, Figure 1). In the remaining analyzed disciplines, no adequate connection between predictors and criteria was recorded.

This is a very interesting issue and its analysis should be approached with special attention. Most coaches and athletes know that better reaction time also means better sprint performance. In this regard, Doherty (1985) indicates that a short reaction time has a positive effect on sprint speed, which was confirmed in this study, but in male finalists in the discipline of 100 m. However, some authors (Baumann, 1980; Helmick, 2003) suggest that a good reaction start time affects sprinter performance by only 1–2%. According to the authors' findings (Martin, Buonchristiani, 1995), a reaction time of 200 ms contains only 2% of a 100 m sprint lasting 10sec, or 0.4% of a 400 m sprint lasting about 45 sec.

The authors (Čoh, Tomažin, 2008; Babić, Čoh, 2010) believe that the starting acceleration is one of the most complex segments of sprint running, in which sprint capacities are rationalized and manifested in the running segment with a maximum speed of over 12 m/s. Any lost time due to poor starting reaction, poorly performed start, starting progression and late reaching speed, is difficult or impossible to make up for in the rest of the race (Smajlović, Kozić, 2006).

In recent times, it is evident that a poorly performed start, with a slower starting reaction, does not necessarily mean failure during the race, or weaker placement. This statement is supported by the fastest man on the planet, Usain Bolt, who achieved the fifth time of the starting reaction (160 ms) in the 100 m and the sixth time in the 200 m (180 ms) in the final of the Olympic Games in London, and still took the first places. These allegations confirm previous research (Martin, Buonchristiani, 1995) which claims that for the final result in the sprint (100 m and 200 m) the length of acceleration, the achieved maximum speed and speed endurance are more important. Similar conclusions can be drawn for our sample of finalists, where the first place was not taken by those finalists with the best starting reaction time, but by those who had the best starting acceleration, running on the track and speed endurance. According to Pavlović (2015), the optimal coherence between the start of the sprint and the starting acceleration are specific motor problems that the athlete must integrate in terms of temporal and spatial parameters into a unipolar movement of a cyclic character.

The time of the starting reaction and the realization of the starting acceleration in the sprint are correlated with the manifestation of the force of isometric and isotonic muscle contraction on the starting blocks, positions and angles in the knee joint, horizontal and vertical impulse (Hunter, Marshall, McNair, 2005). Čoh, Tomažin, Štuhec, (2006) analyze and identify the main kinematic parameters in the phase of sprint and starting acceleration that affect the overall result. They proved that the optimal distance of the blocks, the speed of leaving the starting blocks, the length of the first step, the height of the center of gravity in the first three meters of acceleration, the optimal ratio between the length and frequency of steps are key success factors in two phases of sprint running. According to Lehman and Voss (1997) contact phase after the start and during the race are one of the most important generators of success in the realization of sprint speed and even the final result. This phase must be as short as possible with the optimal ratio of the reflection phase and the flight phase, while the step frequency depends on the functioning of the CNS and is genetically determined, higher step frequency, shorter step and vice versa (Mero, Komi, Gregor, 2003), which is again an individual tactic of each sprinter.

Earlier results of world-class sprinters achieved at the Olympic Games (Babić, and Delalija, 2009; Baumann, 1980) show that with the extension of the section (track), the start reaction time increases linearly, with the reaction time of male sprinters being shorter than that of female sprinters. These allegations were confirmed in the current study, where the male finalists were on average more successful (faster) in the starting reaction than the female sprinters in all three disciplines. Gürses and Kamiş (2018) show that the above statements about the importance of the reaction time in short distances are correct. In a large analyzed sample of elite athletes, the obtained results showed a moderate correlation between the mean values of the 60m sprint results and the reaction time in all categories ($r = 0.436$, $p < 0.01$). In this way, they confirmed that reaction time is of great importance for running performance. Pilianidis, Mantzouranis, Kasabalis (2012) investigate the relationship between reaction time and sprint in the 60 m, 200 m and 60 m hurdles of athletes who participated in the 1997 and 2009 World Championships. They found a significant correlation between reaction time and running at 60 m ($r = 0.323$, $p < 0.05$). Also, Tonnessen et al. (2013) found a significant correlation between reaction time and performance at 100m in male athletes ($r = 0.292$) and females ($r = 0.328$) for the level of significance ($p < 0.01$). This shows that shorter reaction times also mean better sprint performance. Identical results were confirmed in this study but only for the male 100 m run sample (0.230; $p < 0.05$), but not in the 200 m and 400 m disciplines. Theoretically, a shorter reaction time has a positive effect on acceleration and speed continuity, especially on the performance of 60 m, partly on 100 m, which has been confirmed by previous research (Gürses, Kamiş, 2016).

Pilianidis, Kasabalis, Mantzouranis, Mavvidis (2012) also investigate the relationship between the reaction time of sprint and hurdle finalists at the Olympic Games (Sydney, Athens and Beijing). Their study suggests that the mean reaction time increases with increasing distance traveled, which is consistent with the results of our study, where reaction time increased from 150.95ms (by 100 m) to 177.91 ms (by 400 m) which is 26.96 ms at male finalists and from 160.64 ms (for 100 m) to 196.30 ms (for 400 m) for female finalists, which is 35.66 ms (Table 1). Also in terms of gender differences of finalists, the obtained results of this research confirmed a shorter reaction time of male than female finalists, which is in line with some earlier research results (Pavlović, Raković, Idrizović, Mihajlović, 2013; Moravec et al. 1988; Babić, Delalija, 2009). They agree that a longer distance (path length) also means a longer reaction time, i.e. that the reaction time is not of great importance for the result success. Studies (Smajlović, Kozić, 2006) have confirmed that the start time of the reaction in the sprint is not in direct correlation with the final result in either male or female sprinters, which is contrary to the results (Pilanidis, Shalfawi, Tonnessen, 2012). Also, the conclusion that the reaction time increases linearly with the extension of the section (Babić, 2008; Babić, Delalija, 2009; Baumann, 1980) cannot be fully accepted. As an argument against this statement, there are lower mean values of reaction time achieved in the 400m final in London for men compared to 100 m and 200 m (Pavlović, Idizović, Vrcić, Mosurović, 2014).

What is evident is the fact that the prediction of reaction time in sprint disciplines cannot predict the final time at 200 m, 400 m compared to 60 m, 100 m, due to longer running on the finish line (Collet, 2000; Komi, Ishikawa, Jukka, 2009). However, research (Stevenson, 1997; Michael, Jarver, 2002; Henson, Cooper, Perry, 2002) has shown that athletes with better reaction times at the beginning of the sprint had a significant psychological advantage over their opponents, which in many races can be important at the finish level. In other words, the reaction time is not a criterion for long distance races such as 400 m (Collet, 1999), which was also confirmed by the results of this research on a large elite sample of World Championship finalist sprinters.

Conclusion

Based on all previous arguments the presented in the text, the current study showed that the reaction time cannot be a reliable and quality predictor of the result success in sprint running (200 m, 400 m), while in shorter runs (100 m) it has a partial impact, which is confirmed by this research, but only for the male sample ($r = 0.230$, $^{p < 0.044}$), which is also supported by some previous similar research on a sample of top athletes. Although they are different results in terms of reaction time and impact on result performance, they can still serve as a kind of guide in understanding and defining a successful model in sprint running. Also, coaches and athletes can implement certain training aimed at improving the reaction time for competitive races in order to improve the overall athletic performance, but together with all other segments of the race.

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