Reaction Time Trends in the Women's Sprint and Hurdle Events at the 2004 Olympic Games

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ABSTRACT

Reaction time values, though very small, can differentiate overall performance results in sprint races, where the margin of victory is often measured in thousandths of a second. The purpose of this research was to study the reaction time characteristics for the athletes competing in the women's sprint and hurdles events at the 2004 Olympic Games in Athens and to determine differences between events and between the competitive levels of the athletes. The sample of 250 female athletes was selected from the list of competitors and divided by event and by how far the athletes advanced in their competitions (qualification rounds, semi-finals and finals), which defined their competitive level. The results showed statistically significant differences between the events, confirming the findings of earlier studies. Although no statistically significant differences between the competitive levels were found in most of the events, certain differences were established in the 100m, 400m and 100m hurdles. In the 100m and 400m, the differences showed a negative trend, while the 100m hurdles showed a positive trend. Based on these findings, reaction time can be considered as one of the possible determinants of athletes' competitive quality. In a separate article, the results presented here are compared to those of the male participants at the Games.

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Introduction

It sometimes seems as if sport events, and the athletes competing in them, have already reached such a level of performance that further improvement is nearly impossible[1,2,3,7,20,21,22]. We know that athletes are indentified and selected according to the ideal anthropological characteristics for their event and that sport science has established optimal methods for preparation. Despite this, there remain differences in the execution of a competition that determine results and achievements. Keeping in mind that winning margins can be measured in millimetres or thousandths of a second, we can see the necessity to investigate each possibility for advantage.

Every sport action begins with a certain movement. To maximise any advantage that might be gained, it is important to understand what precedes the movement. Revealing the very beginning, that tiny period of time in which a movement is initiated, enables breakthroughs that can contribute to the final performance.

Since an athlete acts voluntarily to start a movement, every move he/she makes begins with a response to a stimulus. The response can be either complex or simple, depending on whether the stimulus is variable or fixed. "Reaction time" denotes the interval from the presentation of a stimulus to the initiation of the response, in other words, the time between the occurrence of the stimulus and the athlete's response. It is clear that reaction time will be of importance in timed activities that are characterised by great movement speed, like, for instance, the sprint and hurdle events in athletics. Speed has been defined as the ability to react and perform single or multiple movements in a short time period. As a motor ability, speed is to a great extend inherited[9,12,15]. However, some studies show that appropriate training methods can enhance speed, especially the speed of performing complex movement structures[4,8].

Reaction, and therefore reaction time, mostly depends on how fast nerve impulses are transmitted from the sensor system (auditory) to the effectors system (muscles). An athlete's reaction at the start of a race in athletics begins with the following sequence:

1. The start signal (the firing of the starter's gun) occurs.
2. The sound travels from the starter's gun to athlete's ears.
3. The ear registers the sound and sends the impulses to the brain.
4. The brain processes the sound, sends out the signal for the start of the action.
5. The muscles receive the signal and athlete begins his/her action.

The reaction time in the sprint events encompasses two different components: the time from the start signal until the push on the starting blocks commences, which is called latent reaction time, and the time from the first push until the athlete has pushed off and left the starting blocks, which is called the motor component of start reaction.

For elite athletes the latent reaction usually lasts from 0.10 to 0.18 sec. The latent reaction time for simple reactions is influenced by two factors: the regulation of neuromotor apparatus and the motor structure of the movement. Studies of various sports show that the first ability is by and large hereditary. Therefore it is not connected to the athlete's physical conditioning level and it does not respond to training. Since it cannot be significantly improved, training must be oriented towards the second factor.

On the signal from the brain, tension in the muscles starts to increase. This is followed by isometric contraction, which transforms into the isotonic explosive contraction and the push on the starting blocks begins. The elapsing time between the start of push on the start blocks and the push-off in elite sprinters lasts between 0.22 and 0.45 sec[21].

There are factors that limit reaction time in the sprint events. These include the duration of set period, when the athletes are held in the "set" position just prior to the start signal, and the way a sprinter prepares his/her response to the start signal. A set period that lasts from one to four seconds is considered optimal and therefore likely to result in the fastest reaction times. This duration is well reasoned because it takes at least one second for the athlete's response preparation and it is hard to maintain the prepared response for longer than four seconds. Another characteristic of the set period is its variability. A constant duration from race to race would enable guessing or anticipation of the start signal and therefore variable set periods are used to prevent athletes from gaining an advantage in this way. Nevertheless, anticipation is a strategy that athletes do use in an effort to reduce the response time to the stimulus. However, there is a known physical limitation to how fast a person can react to a signal and the IAAF has set the limit at 0.100

sec[11]. If an athlete moves earlier than that, it is considered very likely that he/she anticipated the start signal and, according to the rules, the start will be recalled.

An athlete can use two sets of response to the start signal: the sensor set and the motor set. The sensor set is used when the athlete focuses on the stimulus to which he/she will respond, whereas the motor set is used when he/she focuses on the move he/she will make after the stimulus. It has been demonstrated that responses to the sensor set are faster than the ones to the motor set[17].

There are not many available research studies dealing with the characteristics of reaction time, or its influence on the sprint race result[5,6,10,13,14,16,18,19,23]. To our knowledge, investigations of the reaction time characteristics at different competitive levels have not been published, even though it can be expected that higher competitive level athletes will have better reaction time values.

Therefore, the aim of our research was to study the world's top-level athletes as they competed at the 2004 Olympic Games in Athens. We wanted to establish the differences and trends in reaction time for the various sprint and hurdle events and whether within each particular event there are differences across the competitive levels of the athletes, as defined by the furthest round they reached in their event in Athens. In this article we examine the female athletes and in a separate article we will compare the findings with data collected on the male participants.

Methods

Subjects

The subject population of this research consists of women who are involved in long-term systematic athletic training and are defined as healthy individuals with an above average quality of anthropologic characteristics. The sample (N=250) was extracted from the population and it consisted of female athletes who managed to qualify and perform at the 2004 Olympic Games in Athens. The sample can be divided into multiple sub-samples on the basis of the following criteria:

- with regard to performance in the specific events - 100m, 200m, 400m, 100m hurdles, 400m hurdles and the heptathlon events: 200m and 100m hurdles;
- with regard to the round – qualification (first and second rounds), semi-finals and final.

Variables

For all the athletes who started their races from blocks and for all the rounds the following values were registered:

- race result (ROI);
- reaction time (RT);
- season's best result (SB);
- personal best result (PB);
- age (YRS).

The race result was measured by the official electronic timing system and our data was taken from the official results. Reaction time was measured by the electronic starting blocks and the results were automatically registered with the computer program of the electronic system "OMEGA". These data were announced publically and were given to the athletes, coaches and media.

Data analyses

Descriptive statistics (mean, standard deviation, range) ware calculated from the obtained data. The analyses of the differences in reaction time between the different sub-samples were tested by the Student's T-test for independent samples. Statistical analyses were performed on the data from the first round, semi-final and final races. All the differences were considered significant at the level of $p<0.05$. Athletes who performed in a later round were left out of the analysis of earlier rounds.

Results

Descriptive statistics

Descriptive parameters of reaction time for the sprint and hurdle events are presented in Table 1.

Table 1: Descriptive parameters of reaction time (sec) for the women's sprint and hurdle events at the 2004 Olympic Games

Event	N	Mean	Min	Max	SD	Skew	Kurt	Max D
100m	50	0.184	0.140	0.250	0.022	0.699	1.429	0.080
200m	38	0.212	0.149	0.346	0.045	1.022	0.826	0.140
400m	35	0.281	0.179	0.461	0.068	1.105	0.826	0.164
100m H	34	0.188	0.145	0.279	0.033	1.129	0.816	0.158
400m H	32	0.292	0.184	0.408	0.057	0.052	-0.957	0.137
Hep 100m H	30	0.207	0.150	0.272	0.027	0.143	0.015	0.081
Hep 200m	31	0.238	0.180	0.347	0.041	0.524	-0.030	0.106

TEST50=0.188; TEST38= 0.210; TEST35= 0.224; TEST34= 0.224; TEST31= 0.242; TEST30= 0.242 (p=0.05). Number of subjects (N), average value (MEAN), minimal (MIN) and maximal (MAX) result, standard deviation (SD), coefficients of variability: skewness (SKEW) and kurtosis (KURT), and deviation of the relative cumulative empirical frequency from the relative theoretical frequency (Max D)

Table 2: Descriptive parameters of reaction time (sec) for the rounds of the women's sprint and hurdle events at the 2004 Olympic Games

Event	Level	N	Mean	Min	Max	SD	Skew	Kurt	Max D
100m	F	8	0.185	0.154	0.212	0.020	-0.184	-1.006	0.123
	SF	8	0.168	0.140	0.200	0.018	0.457	1.185	0.184
	Q	34	0.188	0.147	0.250	0.022	0.889	1.976	0.152
200m	F	8	0.199	0.162	0.259	0.031	0.886	1.044	0.169
	SF	7	0.238	0.172	0.346	0.062	0.987	0.106	0.296
	Q	23	0.208	0.149	0.292	0.042	0.590	-0.692	0.195
400m	F	8	0.245	0.205	0.276	0.024	-0.419	-0.579	0.145
	SF	15	0.304	0.207	0.436	0.072	0.551	-0.512	0.118
	Q	12	0.276	0.179	0.461	0.076	1.325	2.227	0.231
100mH	F	7	0.161	0.145	0.195	0.018	1.575	2.172	0.286
	SF	7	0.171	0.160	0.187	0.008	0.765	0.910	0.172
	Q	20	0.202	0.154	0.279	0.034	0.682	-0.260	0.148
400mH	F	8	0.288	0.184	0.408	0.066	0.328	1.078	0.179
	SF	6	0.304	0.206	0.387	0.077	-0.157	-2.563	0.268
	Q	18	0.290	0.218	0.355	0.050	-0.183	-1.643	0.173

TEST34=0.224; TEST23=0.275; TEST20=0.294; TEST18=0.309; TEST15=0.338; TEST12=0.375; TEST8=0.454; TEST7=0.483; TEST6=0.519 (p=0.05). Number of subjects (N), first round (Q), semi-final races (SF), final race (F), average value (MEAN), minimal (MIN) and maximal (MAX) result, standard deviation (SD), coefficients of variability: skewness (SKEW) and kurtosis (KURT), and maximal deviation of the relative cumulative empirical frequency from the relative theoretical frequency (max D)

On the basis of the average values for reaction time for all the events studied, it was found that the best average reaction time was achieved, as expected, in the shortest races – 100m and 100m hurdles. From the obtained values of skewness and kurtosis coefficients and from the Kolmogorov-Smirnoff test, it can be concluded that reaction time values of all the events studied had normal distribution.

Table 3: The analysis of average reaction time differences (sec) between the women's sprint and hurdle events at the 2004 Olympic Games

Events	Mean	SD	Mean	SD	t-value	p	df	F
100:200 (N=50, N=38)	0.184	0.022	0.212	0.045	-3.749	0.000	86	4.105
100:400 N=50, N=35)	0.184	0.022	0.281	0.068	-9.349	0.000	83	9.410
100:100H (N=50, N=34)	0.184	0.022	0.188	0.033	-0.552	0.582	82	2.132
100:400H N=50, N=32)	0.184	0.022	0.292	0.058	11.871	0.000	80	6.709
100:H100H (N=50, N=30)	0.184	0.022	0.207	0.027	-3.994	0.000	78	1.474
100:H200 (N=50, N=31)	0.184	0.022	0.238	0.041	-7.616	0.000	79	3.392
200:400 (N=38, N=35)	0.212	0.045	0.281	0.068	-5.151	0.000	71	2.292
200:100H (N=38, N=34)	0.212	0.045	0.188	0.033	2.579	0.012	70	1.925
200:400H (N=38, N=32)	0.212	0.045	0.292	0.058	-6.493	0.000	68	1.634
200:H100H (N=38, N=30)	0.212	0.045	0.207	0.027	0.555	0.581	66	2.784
200:H200 (N=38. N=31)	0.212	0.045	0.238	0.041	-2.489	0.015	67	1.210
400:100H (N=35, N=34)	0.281	0.068	0.188	0.033	7.220	0.000	67	4.413
400:400H (N=35, N=32)	0.281	0.068	0.292	0.058	-0.678	0.500	65	1.403
400:H100H (N=35, N=30)	0.281	0.068	0.207	0.027	5.601	0.000	63	6.382
400:H200 (N=35, N=31)	0.281	0.068	0.238	0.041	3.063	0.003	64	2.774
100H:400H (N=34, N=32)	0.188	0.033	0.292	0.058	-9.089	0.000	64	3.147
100H:H100H (N=34, N=30)	0.188	0.033	0.207	0.027	-2.519	0.014	62	1.446
100H:H200 (N=34, N=31)	0.188	0.033	0.238	0.041	-5.498	0.000	63	1.591
400H:H100H (N=32, N=30)	0.292	0.058	0.207	0.027	7.346	0.000	60	4.550
400H:H200 (N=32, N=31)	0.292	0.058	0.238	0.041	4.247	0.000	61	1.978
H100H:H200 (N=30, N=31)	0.207	0.027	0.238	0.041	-3.504	0.001	59	2.300

Average value (MEAN), standard deviation (SD), coefficient of t-test value (t-value), significance level (p), degrees of freedom (df), table values of F distribution (F)

It can be observed from Table 1 that reaction time values increase as the race distance increases, which is in accordance with the results of previously conducted research studies[5,13, 19, 23].

Basic descriptive parameters of reaction time for the rounds of each event are presented in Table 2. The heptathlon events are not included because their competition system involves no rounds.

From Table 2 it can be observed that the results do not statistically exceed the normal distribution. The analysis of the average reaction time values in the rounds of each event shows that the best average reaction time values were accomplished in the finals with the exception of the 100m, where the best value was found in the semi-finals. In all the other events, with exceptions in the 100m and 100m hurdles, the average reaction time values were the poorest in the semi-finals.

Reaction time differences between events

The results of the differences in reaction time between events are presented in Table 3.

The Student's T-test showed that differences in reaction time existed between most

Table 4: The analyses of average reaction time differences (sec) between competitive levels within the women's sprint and hurdle events at the 2004 Olympic Games

Event	Level	Mean	SD	Mean	SD	t-value	p	df	F
100m	F:SF	0.185	0.020	0.168	0.018	1.860	0.084	14	1.344
	F:Q	0.185	0.020	0.188	0.022	-0.282	0.779	40	1.204
	SF:Q	0.168	0.018	0.188	0.022	-2.373	0.023	40	1.617
200m	F:SF	0.199	0.031	0.238	0.062	-1.553	0.144	13	4.097
	F:Q	0.199	0.031	0.208	0.042	-0.528	0.602	29	1.894
	SF:Q	0.238	0.062	0.208	0.042	1.464	0.154	28	2.163
400m	F:SF	0.245	0.024	0.304	0.072	-2.203	0.039	21	9.165
	F:Q	0.245	0.024	0.276	0.076	-1.106	0.283	18	10.169
	SF:Q	0.304	0.072	0.276	0.076	0.959	0.347	25	1.110
100mH	F:SF	0.161	0.019	0.171	0.009	-1.145	0.172	12	5.100
	F:Q	0.161	0.019	0.202	0.034	-2.816	0.009	24	3.316
	SF:Q	0.171	0.008	0.202	0.034	-2.483	0.020	26	16.909
400mH	F:SF	0.288	0.066	0.304	0.077	-0.401	0.695	12	1.366
	F:Q	0.288	0.066	0.290	0.050	-0.096	0.924	24	1.737
	SF:Q	0.304	0.077	0.290	0.050	0.485	0.633	22	2.373

Average value (MEAN), standard deviation (SD), coefficient of t-test value (t-value), significance level (p), degrees of freedom (df), table values of F distribution (F)

sprint events, in favour of shorter events. This finding was expected because the increase of reaction time values with the increase of race distance. These results confirmed again the results of previous studies[5,13, 19, 23]. It can be seen from Table 3 that no statistically significant difference in reaction time was found between the following events:

- 100m and 100m hurdles: p=0.582
- 200m and heptathlon 100m hurdles: p=0.581
- 400m and 400m hurdles: p=0.500.

Reaction time differences between rounds within events

The results of the Student's T-test for the analysis of average reaction time differences between the competitive levels within each event are presented in Table 4.

It can be observed from Table 4 that statistically significant differences were found for:

- 100m: between the average reaction time of the first round and the semi-finals, in favour of the semi-finals (mean=0.168, p=0.023)
- 400m: between the average reaction time of the semi-finals and the final, in favour of the final (mean=0.245, p=0.039)
- 100m hurdles: between the average reaction time of the first round and the semi-finals, in favour of the semi-finals (mean=0.171, p=0.020) and between the first round and the final, in favour of the final (mean=0.161, p=0.009).

The average reaction time differences between the rounds within events were not found; their significance level was greater than 0.05. Nevertheless, one of the results of this analysis should be pointed out: the analysed differences in reaction time between the final and the semi-final races of the 100m are very close to being statistically significant (p=0.084).

Discussion

The results show that with the increase of race distance the average reaction time value increases significantly. This confirms the results from the previous studies, like those from the 1987 World Championship in Athletics[19], the 1988 Olympic Games[5], the 1993 World Championship in Athletics[13] and the 1994 European Athletics Championships[13].

One of the possible explanations for this phenomenon is that the athletes competing in the longer events know that reaction time makes a smaller contribution to the final race time or result and so, most likely, do not pay as much attention to that part of the race during their training. For them, even though the push off phase from the start blocks is important, it is not a priority, so their reaction times last longer.

The other possible explanation for such a result can be found in the set of responses that the athletes in particular sprint events use during the start. Since it was found that responses with the sensor set are faster than the ones with the motor set, we assumed that the athletes in shorter sprint events (100m, 100m hurdles) were using the sensor set of responses, whereas the athletes in all the other events were using the motor set of responses. In other words, the latter focused on the move following the stimulus, which caused their reaction times to be longer.

The 200m, 400m, 400m hurdles, heptathlon 200m and heptathlon 100m hurdles each impose specific structural and biomechanical demands on athletes competing in them. For instance, the running in 200m consists of the start on the curve then athletes leave the curve and the final part of the race is performed on the straight part of the track. The 400m and 400m hurdles put even bigger demands on the athletes since they require a high level of speed endurance, movement economy and a precise running rhythm. Due to their particular characteristics, each of these events also requires a specific tactical approach, which begins with the start action itself. By taking this into consideration, the assumption that the athletes in the 200m, 400m, 400m hurdles, heptathlon 200m and heptathlon 100m hurdles were using the motor set of responses to the stimulus gains more solid grounds.

Due to the established reaction time characteristics of particular events, it is not surprising that statistically significant differences in reaction time values were found between most sprint events (Table 3). However, the obtained results of the Student's T-test did not show any statistically significant differences in reaction time between the hurdle events and the same distance flat events (100m/100m hurdles, 400m/400m hurdles). This shows that the existence of hurdles 13m from the start line is not a limiting factor in reaction time and it is consistent with previous findings[13]. Even for events that are rather different from a structural and kinematic point of view, like the 200m and heptathlon 100m hurdles, there were no significant differences in reaction times. It seems that other characteristics of the particular events, apart from their distance, have a role in reaction time duration and can serve as possible explanations of the differences or similarities in reaction time values of particular events.

The Olympic Games imply high quality competition and a high achievement level. In order to succeed, athletes must have appropriate anthropological characteristics and be well prepared. The competition system for the sprint events includes multiple rounds. Therefore, the athletes' capability should be consistent with the level of competition in each round and the differences in competitive quality should be obvious. It was expected that the reaction time could be the determinant of possible differences in competitive quality of athletes; that the average reaction time values within a particular event should be better through the rounds. It was observed that for most sprint and hurdle events, the reaction time values were the best in the finals (Table 2). Despite that, within most events statistically significant differences in reaction time values between the rounds were not found (Table 4). Therefore, it can be concluded that, with regard to reaction time, the athletes in most of the sprint and hurdle events at the 2004 Olympic Games in Athens were at somewhat equal competitive quality level through all the rounds.

Nevertheless, some of the obtained results show a certain statistical significance, in that way implying that the reaction time values were the determinants of the differences in competitive quality for some events and their rounds. The observed differences in reaction time values of the competitive levels in the 100m and in 400m do not have attributes of competition round progressivity, but of oscillation.

The significant difference in reaction time values between first round and semi-final races in the 100m can be explained as the athletes in the semi-finals had literally used their all reaction time capacities. The excitation level of the central nervous system of athletes who competed in the semi-final races confirms the importance of reaction time in shorter sprint events and this significant difference only emphasises that more. The height of the excitation level also shows the importance of progressing to the finals of the 100m at the Olympic Games. However, the demands were so high that the athletes in the finals were not able to repeat or exceed their functional capacities of the central nervous system, which is best manifested in the reaction time. The average reaction time value in the finals was slightly better than the first round but when compared, the difference was, unexpectedly, not statistically significant. The regressive oscillation of the reaction time values, in other words, of the competitive quality of athletes in the finals of the 100m, can be best seen from this analysis. This leads to the conclusion that the 2004 Olympic final in the 100m did not justify its reputation as the best sprint event in the world; quite the opposite - from the reaction time point of view – the values were inferior to the semi-finals.

Unlike the 100m, the analysis of reaction time values from the rounds of the 400m points to the opposite conclusion from that mentioned above. The statistically significant difference in reaction time values emphasises a somewhat slower reaction time for athletes in the semi-finals compared to the final. Unlike the finals of the 100m, the athletes in the 400m final showed appropriate reaction time capacities. Since it is assumed that the reaction time in the 400m does not have as much importance as in shorter events, it is likely that the athletes in the semi-final race were not "calculating" with reaction time but simply "fell asleep" at the start.

The further statistically significant differences in reaction time found between the first round, the semi-finals and the final of the 100m hurdles can be a clear sign of the high competitive quality level of the athletes participating in the final. Since within all the other events the differences were not found to be significant (except between the first round and the semi-finals of the 100m, keeping in mind that the finals did not justify realistic expectations), and due to the progressive trend of the average reaction time values from the first round through to the finals, the athletes of this event seemed to be the best prepared for the start. In other words, we can say that from the standpoint of reaction time, the 100m hurdles was the highest quality women's sprint and hurdle event at the 2004 Olympic Games.

Conclusion

The purpose of this research was to determine the differences in reaction time between sprint events as well as between the rounds within each event.

The results show that with the increase of race distance the average reaction time value significantly increases. Statistically significant differences in reaction time between most events were obtained. However, statistically significant differences between the hurdle events and the same distance flat events

(100m/100m hurdles, 400m/400m hurdles) were not found.

With regard to the high competition level at the Olympic Games, it was expected that the reaction time values and trends could be the determinants of the differences in athletes' competitive quality. By the analyses of average reaction time between the competitive levels within each event, statistically significant differences in reaction time values between the rounds, and thus the level of the athletes making it through to each round, were mostly not found. This result led to the conclusion that, with regard to reaction time, the athletes in most sprint events at the Olympic Games in Athens were of a somewhat equal quality level through all the rounds of the analysed events. However, the observed differences in reaction time values between certain rounds of some events (100m and 400m) pointed to regressive oscillations of the athletes' competitive quality. On the other hand, the differences within the 100m hurdles event pointed out the progressive trend of reaction time values through the rounds, and, thus, a progressive trend in the athletes' competitive quality, which met the expectations of this research.

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