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Comparative Analysis on Speed Distribution of Women 400m Finalist Athletes in the World Athletics and Olympic Championships.

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Abstract

The 400m dash sprint is considered to be one of the most interesting and difficult sprint events in the sport of athletics, this is why sports scientists are paying much attention now to develop the means of helping athletes to enhance their performance and numerical achievements through investigating the mechanical and kinematical and other scientific variables of the race trying to obtain reliable results as a base for modern training techniques. This study aims for presenting a comparative analysis on speed distribution of women 400m finalist athletes in the world athletics 2011 and 2012 Olympic championships by means of correlation analysis, regression analysis and cluster analysis, every 50m segment result has been studied as well as total results of world elite women 400m athletes. The main purpose is to reveal the relations between different 50m phases and the final 400m result, and to find out the basic features of their speed distribution, in order to provide scientific references for our women athletes to increase the ability of reaching higher performance levels.

Key Words: *women, world, 400m, analysis, speed, distribution*

Introduction

The 400 meters, or 400 meter dash, is a common sprinting event in track and field competitions. It has been featured in the athletics program at the Summer Olympics since 1896 (1964 for women). On a standard outdoor running track, it is exactly one lap around the track. Runners start in staggered positions and race in separate lanes for the entire course. In many countries, athletes previously competed in the 440 yard dash (402.336 m)—which is the length of a quarter of a mile and was referred to as the 'quarter-mile'—instead of the 400 m (437.445 yards), though this distance is now obsolete. An athlete who competes in the 400 m may still be referred to as 'quarter-miler'. Maximum sprint speed capability is a significant contributing factor to success in the event, but athletes also require substantial speed endurance and the ability to cope well with high amounts of lactic acid to sustain a fast speed over a whole lap. While considered to be predominantly an anaerobic event, there is some aerobic involvement and the degree of aerobic training required for 400 meter athletes is open to debate. This totally agrees with Safaa's "1986" and Yassin's "1989" findings who confirmed the presence of lactic concentration level elevation in blood that reaches 120 up to 200 Mlgm/100 ml in short distance running.

The current women's world record is held by Marita Koch, with a time of 47.60 seconds. Grenadan Kirani James is the reigning men's Olympic champion, while LaShawn Merritt holds the world title; Christine Ohuruogu is the reigning women's world champion, while Sanya Richards-Ross holds the women's Olympic title. Running the race of 400 meter needs courage in choosing that event which is uniquely challenging. There will be a point in the 400m when you will have to ask yourself am I going to compete or am I going to cave?" Michael Johnson, who won the 200 meter and 400 meter at the 1996 Olympics - and still holds the 400 meter world record of 43.18 set in 1999 - explains the difficulty of the 400 meter succinctly: "No one can run 400 meters at full speed from the gun". Thomas "2013" agrees with Hurst "2013" and other athletics' researchers and scientists who divided the ultimate strategy for performing this challenging event into the following:

First 100 Meters: It is better not being too aggressive out of the blocks. It is better to focus on staying smooth as the field establishes a pace for the race. The best advice is to run just below the top speed. If someone is running inside you, keeping pace with them means you're actually running faster, since you're running farther by being on the outside.

Second 100 Meters: The key to this part of the race is to run in a controlled sprint without pushing too hard. Your face and body shouldn't show any strain. If you run too hard, your muscles tighten, stride shortens and you slow down. Johnson tried to relax and neither slow down or speed up. He usually didn't make a move toward the lead until later in the race.

Around the Turn: When you hit the far turn, you'll start to feel the pain of the 400 meter. You have to shift gears and feel like you are picking up the pace, even though research proves that every 400-meter runner slows down during the final half of the race. Johnson says you have to increase your energy at this point and force yourself to maintain your pace. Research shows that elite runners become more fatigued than less-experienced runners, which seems to indicate a greater commitment on their part and/or a higher capacity to run through their fatigue.

Homestretch: Expect your lungs to be bursting and your legs to be burning as you drive toward the finish line. The key is to stay relaxed and maintain good form as you sprint down the stretch. Of course, this is easier said than done. Johnson, who usually tried to take the lead coming off the curve, concentrated on keeping his arms and legs going straight up and down and his head straight as well. By avoiding any side-to-side movement, Johnson ran as efficiently as possible despite his fatigue as he thundered to the tape.

Other experienced track coaches slightly had differences in their opinions concerning the 400m dash strategies for either men or women. Hogan "2013" stated that 400m racing can be divided into 3 stages as follows:

Step 1: 400 meters should be started at top sprinting speed without winding

Step 2: Relax and settle into your established pace during the second 100 meters. Maintain that pace through the third 100 meters, getting ready to bolt for the finish.

Step 3: Keep your pace up during the final 100 meters. Don't assume you should speed up because it's straight. Pump your arms hard and maintain your pace. If you can, increase the pace as you approach the finish line, running through it instead of slowing down in anticipation.

Researchers also pointed out that the physiological state of the sprinter's body has a great effect on the speed during the race as the aerobic system is the slowest to power up, it is the weakest, but it has the highest capacity. That capacity is barely tapped in a 400m race, but the system plays the vital role of propping up a fading lactic system. The better the aerobic system the faster the pace it can sustain, and so the more support it can provide to the lactic system. The more the race progresses the greater the proportion of the total power that comes from the aerobic system. A weak aerobic system will cost a runner dearly in the final stages of the race.

H. Mohamed "1988" and M. Mansour "2003" both agreed that high level athletes are mostly fully aware of their required kinematical duties as well as the level of speed and time required for performing each segment of their races in addition to the amount of effort that is done to recover this segment.

John and Resse "2003" also confirmed that middle distance sprinters have a specific rhythm while performing their races as they have full control on the levels of speed and the full ability of distributing effort and energy over the whole distance.

Multivariate statistical analysis is a theory and method to solve multi-exponential problems by using symbolic statistic method. With the development of computer application techniques and the stringent need of scientific research, multivariate statistical analysis is applied diffusely in geology, weather, hydrology, industry, agriculture, economy and so on, and has become an effective way to solve practical problems. By searching the literature, we find that multiple analysis is used less in physical education field. This thesis analyzes and compares the every 50m segment time and the speed parameter of athletes taking part in women's 400m finals of the 6th and 7th World Championships in Athletics, analyzes the speed distribution of every 50m segment by multiple analysis and also reveals the speed distribution features of world elite women 400m athletes, in order to provide scientific evidence for our women athletes to control their speeds better, to improve their 400m results and to ameliorate their training methods.

Method and subjects:

Subject

The subjects are the result, speed, and time parameter of the first eight athletes in women's 400m finals of the 2011 world athletics championship and 2012 London Olympics in Athletics. The 2 final races were obtained through the Youtube website as a two HD video files that were downloaded from the internet through Internet download manager as follows:

- 2011 world final: http://www.youtube.com/watch?v=Oy1N98QjxuA
- 2012 Olympics final: http://www.youtube.com/watch?v=RW7BTHm5O58

Then both files underwent the required time analysis on Dartfish software V 5.5 using a high speed PC.

Method

We use multivariate statistic method to analyze the every segment result of world finalist women 400m athletes, dealing the data with SPSS V 11.0.

Data analysis

Simple correlation analysis reflects the weakness of the linear relation between two variables by numbers. Pearson simple correlation coefficient can be used to measure the linear correlation between different scale variables. Through analysis, we will find that the correlation coefficient r=-0.258 between reaction time of start and final 400m result, which shows that starting reaction time has a little effect on 400m result. The absolute values of the correlation coefficients between each 50m segment time and 400m result can be presented in the following descending order: |D8|>|D6|>|D5|>|D7|>|D2|>|D1|>|D4|>|D3| (D1 stands for the first 50m segment, D2 stands for the second one, the rest may be deduced by analogy), which shows that the speed of the rest 200m is very important to the 400m result.

The correlation coefficient r equals 0.903 ($p<0.01$) between the rest 200m and the 400m result. Therefore, to keep a high speed in the rest 200m of 400m is an essential pledge to win the game. Furthermore, the correlation coefficient r equals 0.753 ($p< 0.01$) between the eighth 50m segment time and the 400m result. Thus, on condition that the athletes have

very close technical levels and specialized qualities, we can win the nip and tuck game by improving the final dash ability.

Table 1
Segment Time of Athletes Taking Part in Women's 400m Final of the 2011 World Championship in Athletics (s)

Name	Result (s)	Reaction Time (MSEL) 0-50		Segment (m)						
		RT	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400
1. Amantle MONTSHO	49.56	226	6.54	5.72	5.64	5.80	6.00	6.20	6.60	7.06
2. Allyson FELIX	49.59	167	6.50	5.56	5.76	5.88	6.08	6.24	6.60	6.97
3. Anatasiya KAPACHINSKAYA	50.24	143	6.67	5.56	5.66	5.96	6.17	6.34	6.70	7.18
4. Francene McCORORY	50.45	143	6.44	5.48	5.37	6.36	6.40	6.40	6.74	7.26
5. Antonina KRIVOSHAPKA	50.66	126	6.58	5.72	5.64	5.96	6.10	6.40	6.86	7.40
6. Shericka WILLIAMS	50.79	159	6.62	5.66	5.62	5.96	6.24	6.48	6.85	7.36
7. Sanya RICHARDS-ROSS	51.32	127	6.58	5.72	5.88	6.07	6.30	6.61	6.80	7.46
8. Novlene WILLIAMS-MILLS	52.89	167	6.68	5.96	5.90	6.23	6.44	6.76	6.96	7.96

Table 2
Segment Time of Athletes Taking Part in the Women's 400m Final of the 2012 Olympic Games in Athletics (s)

Name	Result (s)	Reaction Time (MSEL) 0-50		Segment (m)						
		RT	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400
1. Sanya Richards-Ross	49.55	226	6.54	5.72	5.64	5.80	6.00	6.20	6.62	7.03
2. Christine Ohuruogu	49.70	167	6.50	5.56	5.76	5.88	6.08	6.24	6.60	7.08
3. DeeDee Trotter	49.72	143	6.66	5.56	5.56	5.91	6.08	6.24	6.60	7.11
4. Amantle Montsho	49.75	143	6.44	5.48	5.24	6.30	6.20	6.30	6.63	7.16
5. Novlene Williams-Mills	50.11	126	6.58	5.72	5.64	5.76	6.07	6.20	6.74	7.40
6. Antonina Krivoshapka	50.17	159	6.62	5.56	5.52	5.86	6.14	6.30	6.76	7.41
7. Francena]McCorory	50.33	127	6.58	5.62	5.78	6.00	6.20	6.39	6.60	7.16
8. Rosemarie Whyte	50.79	167	6.48	5.76	5.40	5.84	6.24	6.46	6.86	7.75

Partial Correlation Analysis

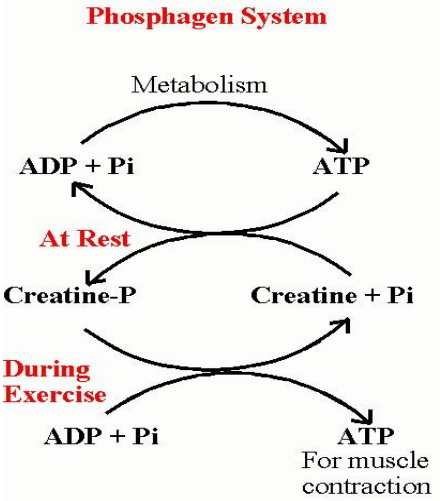
If we want to get the real relation between every two variables, we must calculate their correlation coefficient without the influences of other variables. In order to study the partial correlation between 400m result and eight 50m segment time, we can control the other seven 50m segment time and choose only one to compare with the total result by partial correlation analysis. The absolute values of partial correlation coefficients between each 50m segment time and 400m result can be arranged as:

|D8|＞|D3|＞|D1|＞|D4|＞|D6| ＞|D2|＞|D5 |＞|D7|（Table 3).

Partial correlation analysis can reflect the correlation between each segment speed distribution and 400m result more objectively. From the order we can see that the eighth 50m segment time has the strongest partial correlation with the 400m result, which is in line with the outcome of the correlation. They commonly indicate that the dash ability in the eighth 50m segment has an important influence on the 400m result. Thus, we can develop the dash ability of 400m athletes through specialized trainings, the purpose of which is to increase the energy supply ability of body lactic acid energy system and the ability to tolerate lactic acid in order to improve the dash ability of the last 50m which is an important physiological component of racing.

The second one is the third 50m segment. The energy supply system of this segment changes gradually from phosphagen "Which depends on ATP and PC stored in the muscle cells with small quanities that will not suit long time physical activities" to glycolysis "Glycolysis is a determined sequence of ten enzyme-catalyzed reactions that offers the highest energy component for human body" which embodies in speed drop and time-consuming enhancement. In the third place is the first 50m segment; which reflects the accelerated ability after starting. The task of this segment includes two aspects: one is to conquer physical inertia, which makes the body start rapidly from a relative quiescent state and gradually get the highest displacement speed; the other is to conquer physiological inertia, which makes the body use phosphagen energy supply system firstly at the beginning of sports and then activate glycolysis energy supply system, providing relevant energy according to the need of athletic intensity. Characterized by its rapid metabolism, strong power-output and prior energy use, phosphagen system constitutes the main energy source of stepped-up running. Thereby, the stepped-up running ability of an athlete after start actually reflects the energy supply ability of his phosphagen system. Although phosphagen energy supply system can maintain merely six-eight seconds, its energy supply rate is as 1.9 times as that of glycolysis energy supply system and is as 3.7 times as that of aerobic metabolism energy supply system. This fully agrees with M. Mansour "2003" finding s where he proved that the strategy of speed and energy distribution must be directly proportional to his physiological abilities.

Fig (1)
A brief explanation about the metabolic process of phosphagen energy system



Therefore, the athletic speed produced by phosphagen energy supply plays an extremely important role in stepped-up running after start. Since the first 50m segment demands a high energy supply rate, it has to be supplied energy by phosphagen system only. In training we can develop the accelerated ability of 400m athletes by specialized training means, the purpose of which is to increase the energy supply ability of body phosphagen system and the ability of fast athletics. By means of repetitive training or intermittent training of ultimate and hypo-ultimate intensity whose athletic time are less than 10 seconds, we can increase the content of phosphocreatine and the activity of relevant enzyme.

Fig (2)
A brief explanation about the metabolic process of glycolysis energy system

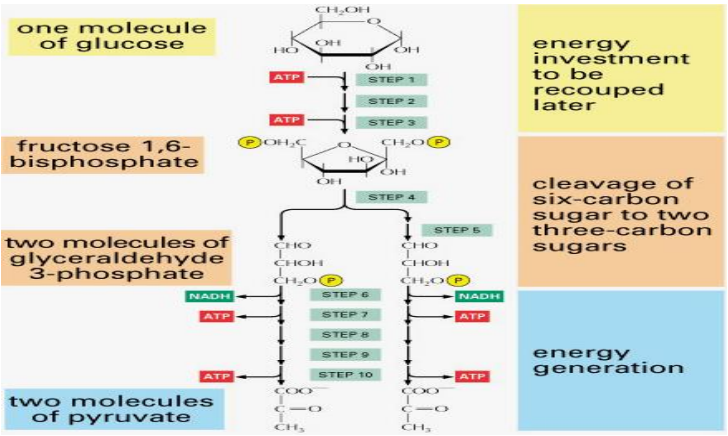


Table 3
Partial Correlation Analysis of the 400m Results and the Eight 50m Segment Time of the 2011 World and 2012 Olympic Championships in Athletics

Segment	D1	D2	D3	D4	D5	D6	D7	D8
Correlative value to the final result	0.9688	0.9378	0.9722	0.9551	0.9032	0.9393	0.8124	0.9775

Regression Analysis of 50m Segment Time and 400m Result (establishing a multiple linear regression model)

Multiple linear regression model is a linear regression model that has many explanatory variables and it is used to reveal the linear correlation between the explained variable and other variables. Since 400m result is affected by eight 50m segment time, we can establish an eight-variable linear regression model, using eight 50m segments to explain the 400m result.

In order to distribute the speed of the eight 50m segments reasonably, we need control the time of every segment according to the regression model, and, sum up the experience and get improvement in peacetime training.

One purpose of establishing a regression model is to control and to predict the object's future developments according to the regression model. Since the adjusting coefficient of determination (0.995) is close to 1, we may come to the conclusion that the homogeneity of this regression model is very high, and the model can explain most part of the explained variable. The significance testing statistics show that F=412.110, P=0.0000<0.01; and the T-level of D1, D2, D3, D4, D5, D6, D7, D8 is 10.338, 7.205, 10.982, 8.533, 5.567, 7.244, 3.686, 12.274 respectively. Moreover, the significance probability is less than 0.05. The construction of this regression model, which makes controlling the whole process of training possible, would be a convenience for the coach to monitor and evaluate training and to arrange every 50m segment speed scientifically according to each athlete's 400m result.

Cluster analysis of 50m segment time and 400m result

Cluster analysis is to sort the sample data on the basis of the chosen variables, and it is an outcome of calibrating every variable synthetically. This thesis analyzes the original statistics with cluster analysis for every segment training of women 400m athletes. Analyzing table 4, we know that if we cluster the eight segments into four categories, the first and seventh 50m segments can be one, the second and third 50m segments can be another, the fourth, fifth and sixth segments is the third; and the eighth 50m segment is the last; if we cluster them into three, the first, fourth, fifth, sixth and seventh 50m segments can be one, the second and third 50m segments can be another, and the eighth 50m segment is the last. These two clusters have some points in common: the second and third segments make up one category, the fourth, fifth and sixth segments belong to another category and the eighth segment constitutes a category singly. The category made up of the second and third segments can be interpreted as a transition segment from stepped-up running to midway running, thus, we can develop the running ability of these two segments by specialized training means, for example, the exercises of 150m-200m fast running and the trainings of multiple jumps. The eighth 50m segment is the sprint stage, which needs to use specialized training to develop the athletes' abilities of anaerobic endurance and body resistance to acids as sprinting needs to higher levels of cardio-vascular and muscular endurance as confirmed by Mahfouz "1986". The category consisting of the fourth, fifth, and sixth 50m segments is a steady running stage, which needs to develop the athletes' ability of high- speed steady running through specialized training means.

Table 4
Members of Hierarchical Cluster Analysis

Segment	4-clustered	3-clustered
1	1	1
2	2	2
3	2	2
4	3	1
5	3	1
6	3	1
7	1	1
8	4	3

Conclusion and discussions

The simple correlation analysis shows that to keep a high speed in the rest 200m of 400m is the key point of winning the game and on the condition that athletes have very close technical levels and specialized results, our athletes can win the nip and tuck game by improving their ability of the final dash. The partial correlation analysis shows that the absolute values of the partial correlation coefficients between every 50m segment time and 400m result can be arranged as:

|D8|>|D3|>|D1|>|D4|>|D6|>|D2|>|D5|>|D7|, which is in line with the outcome of correlation analysis, and shows that to keep the speed of eighth 50m segment is very important. This mostly agrees with Reardon "2012" findings who stated that runners in 400 m and 800 m races are often urged to attempt to run the second half of the race at the same pace as the first ("even splits"), on the grounds that this is the most economical distribution of energy, as no doubt it is. However, almost no successful runners in 400 m and 800 m races actually do this, and the burden of this

paper has been to try to understand why. A simple model of entropy accumulation suggests that for any reasonable relation between entropy generation and speed, the optimal race strategy is to run the first half of the race faster than the second. Such a strategy causes the entropy density gradient across the boundary of the working muscle to take on a large value early in the race, which increases the entropy efflux. That this is in fact the optimal race strategy is proven by the overwhelming preponderance of positive-split races in the set of world records for one-lap and two-lap races. Since there are many other factors that athletes encounter in races, such as the race tactics of other athletes, as well as psychological variables, this analysis may not justify advising an athlete who prefers to run even-split, or even negative-split races, to adopt a different pacing strategy. However, one should not, on the basis of energy arguments, discourage an athlete who prefers to run positive-split 400 m races from doing so, because it may be that the athlete knows best.

In this thesis a Multiple Linear Regression Model between eight 50m segment time and 400m result has been established as follows:

Y=2.160+0.975D1+0.995D2+0.966D3+0.902D4+0.950D5+ 1.079D6+0.769D7+1.045D8

Tests show that this regression model is of outstanding significance and can reflect the relation between 400m result and every segment time truthfully, which provides scientific evidence for the coach to arrange the speed training of every 50m segment running scientifically.

If we cluster the eight 50m segment time of world elite women 400m athletes into three categories or four categories, we will find that they both reflect: the second and third segments are a transition from stepped-up running to midway running and these two segments are inseparable in training; the eighth 50m segment is the sprint stage, which needs to enhance the athletes' dash ability by specialized training; the fourth, fifth and sixth 50m segments make up a high-speed steady running segment, which needs the athletes to keep the ability of longtime steady running.

Recommendations:

Based on these research findings, the researcher recommends the following:

1- Applying further speed analysis researches on different athletic races for men and women as well as juniors to help in adjusting training process according to the findings of each player.

2- Applying advanced means of training to develop the speed in the last segment for its having the greatest effect on the final result of the race.

3- Paying more attention to the physiological aspects of each athlete as it has full effect on the performance of each segment in sprint distance races.

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