KINEMATICS OF MARATHON RUNNING. PART TWO: DISTRIBUTION OF VELOCITY

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The paper presents description of kinematics of marathon courses' data for men and women. The following courses were taken into account: Edmonton 2001, Boston 2002, Berlin 2002, Athens 2004. The purpose of the paper was to investigate tactics of running by mechanical data. The highest mean velocity obtained for the whole distance was 5.55 m/s for men and 5.00 m/s for women. Usually second half of a distance was run slower, but few first runners at the finish ran second half of a distance faster. Not earlier than after 30 – 35 km correlation coefficient between 5 km fragment time and the end time surpassed 0.8 value. Usually first ten runners ran with lower absolute acceleration value.

KEY WORDS: marathon run, tactics, kinematics, time, velocity distribution, acceleration

INTRODUCTION:

Tactics of long distance running takes into account garments worn, especially shoes, undertake a decision whether running lonely or within a group, taking supplements before a run, taking fluids during a run. There is also tactics that takes into account running for the best time ever, i.e., running for a record time and fighting mostly with one's own body, or for championship, i.e., running for passing as the first runner a finish line and fighting with opponents. Within biomechanics of marathon running there is technique of run acquired, leading a group or to hide behind someone's back, distribution of velocity.
Results obtained in marathon running are dependent on geometry of a course. In previous paper (Erdmann and Lipinska, 2006) course profiles of the following marathons were presented: Edmonton 2001, Boston 2002, Berlin 2002, Athens 2004. Courses were divided onto 1 km fragments. Vertical and horizontal distances were calculated in order to obtain tangent for each 1 km fragment. In addition a sum of ascent and descent fragments was obtained and mean data of a profile for the entire course. In order to describe difficulty of particular course a coefficient of course difficulty (Ccd) was calculated /1/:

$$Ccd = [\Sigma (p \times tg\ \alpha)] \times 100 \qquad /1/$$

where: Ccd – coefficient of course difficulty, p – parameter for 1 km course's fragment (a = 1.0 for horizontal, b = 0.8 for descending, c = 1.6 for ascending (based on Costill, 1976), α – angle of descending or ascending hypotenuse of a course's fragment.

The investigated marathon courses' had following Ccd coefficients: Edmonton 8.3, Boston 5.4, Berlin 3.7, Athens 23.4. The latter marathon's profile is one of the most tough profiles in the world – Figure 1.

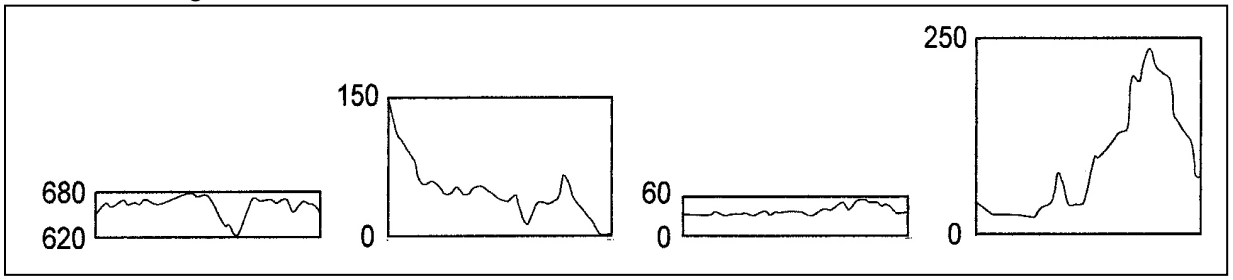

Figure 1: Profiles of the marathons in (from the left): Edmonton, Boston, Berlin, Athens; abscissa – 42195 m, unit of ordinate – m.

The purpose of the entire scientific work was investigation of tactics of running of the best world marathon runners taking into account geometry of the running course. The purpose of this particular paper is a presentation of distribution of velocity of runners along the whole course taking into account geometry of a course.

MATERIAL AND METHODS:

Material: The best 50 male and 50 female runners were taken into account in all four marathons. In this way 400 time data were processed. Runners were divided onto subgroups: ten first at the finish, better half group, worse half group.
Method: For obtaining time data web pages of Organizing Committees were utilized (www.iaaf.results, www.bostonmarathon.org, www.berlinmarathon.de). In addition television broadcasting was used and personal presence during Athens 2004 Olympic marathon. In every marathon times of all 5 km fragments and end fragment (2195 m) were taken for analysis. Data on displacement and time were utilized for calculation of average velocity for every fragment and for the whole distance. Comparing fragments' velocities accelerations / decelerations were calculated, then changed to absolute data of acceleration $|a|$.
For all courses energetic cost was calculated based on ascending and descending of 1 km long fragments. Basic data were taken from Minetti (2002). Above allowed presenting of speed coefficient (SC) of a course calculated as average velocity:

$$v_n = a + (b \times K_n) + (c \times \alpha_n) \qquad /2/$$

where: v_n – average velocity of course's fragment, K_n – cumulated energetic cost of course's fragment, α_n – cumulated slope angle of 5 km course's fragment, a, b, c – parameters.

Based on works of Erdmann and Giovanis (1997) following biomechanical indexes were calculated: 1) Index of runners' level (IRL), 2) Index of velocity's deviations (IVD), 3) Index of runners' endurance (IRE), 4) Relative index of runners' endurance (RIRE):

$$IRL = v / SC \quad /3/ \qquad IVD = |a| / v \quad /4/ \qquad IRE = v_{30\text{-}42} / v_{0\text{-}15} \quad /5/ \qquad RIRE = IRE / v \quad /6/$$

where: v – average velocity for the course, $v_{0\text{-}15}$ – velocity of beginning fragment of marathon, $v_{30\text{-}42}$ – velocity of end fragment of marathon, $|a|$ - absolute acceleration.

Protocol: Edmonton (650 m over sea level) men marathon was carried out on 3rd August 2002 during World Championships. Temperature was 19 ^{O}C, cloudy, start time at 18:45. Women marathon was carried out on 10th August 2001at 16 ^{O}C, cloudy and it started at 8:00. Boston marathon was carried out on 15th April 2002 with temperature 21 ^{O}C and start time at 12:00. Wind 13 m/s was against direction of running, partly cloudy. Berlin marathon was carried out on 29th September 2002 with temperature 14 ^{O}C and start time at 10:00. No wind, cloudy. Athens marathon was carried out during Olympic Games. Course was set along the historic route Marathon – Athens. Women marathon was carried out on 22nd August 2004 at temperature of 35 ^{O}C, sunny, no wind with start time at 18:00. Men marathon was carried out on 29th August 2004 at temperature of 30 ^{O}C, partly cloudy, small wind, start time at 18:00.

RESULTS AND DISCUSSION:

The best time obtained by male runner was about 2 hrs. 07 min. and by female runner about 2 hrs. 21 min. The 50th male runner obtained about 2 hrs 32 min. i.e. 25 min. worse than the best man and 50th female runner obtained about 3 hrs. 14 min. i.e. 53 min. worse than the best woman. Table 1 presents detailed time data and Table 2 presents velocity data of four marathon runs for several groups adopted within this research.
Within male runners correlation coefficient r between time at measuring point for every 5 km and end time acquires a value over 0.8 after 30th km and in Athens after 35th km. It means

that up to 30th km, i.e. roughly after 2/3 of a whole distance, it is hardly to say which place will be occupied by a runner at the finish within 10 first places. Similar was obtained for the better half of runners and for the worse half of runners. Here it is even worse to predict the final order of places. Within female runners above coefficient r differs substantially among the runs. In Edmonton after 35th km a value of r coefficient for 10 first runners at the finish was about 0.6, in Boston it reached 0.8 value after 20th km, in Berlin just after 5th km, and in Athens after 30th km.

Table 1 Time data (hrs.:min.:sec.) of runners at four marathons

Group	Edmonton	Boston	Berlin	Athens
Men				
The 1st	2:12:42	2:09:42	2:06:47	2:10:55
All 50	2:23:28	2:20:17	2:16:29	2:17:51
First 10	2:15:08	2:10:39	2:09:01	2:13:04
Better half	2:19:04	2:14:19	2:11:59	2:15:21
Worse half	2:28:06	2:26:30	2:21:12	2:20:29
The 50th	2:31:42	2:29:47	2:24:55	2:22:37
Women				
The 1st	2:26:01	2:20:43	2:21:49	2:26:20
All 50	2:39:35	2:47:10	2:48:35	2:28:23
First 10	2:28:00	2:28:32	2:31:27	2:27:42
Better half	2:31:20	2:38:34	2:41:27	2:30:37
Worse half	2:47:51	2:56:15	2:56:10	2:45:58
The 50th	3:14:29	3:00:56	2:58:18	2:50:01

Table 2 Velocity data (m/s) of runners at four marathons

Group	Edmonton	Boston	Berlin	Athens
Men				
The 1st	5.30	5.45	5.55	5.37
All 50	4.90	5.01	5.15	5.10
First 10	5.18	5.37	5.43	5.29
Better half	5.05	5.23	5.32	5.20
Worse half	4.74	4.79	4.97	5.01
The 50th	4.64	4.70	4.86	4.93
Women				
The 1st	4.82	5.00	4.96	4.80
All 50	4.43	4.23	4.19	4.40
First 10	4.75	4.74	4.65	4.68
Better half	4.65	4.46	4.38	4.55
Worse half	4.20	3.99	3.99	4.24
The 50th	3.62	3.89	4.09	4.14

If marathon profile and running conditions are easier runners run faster the first half of a course, but not the best runners. In Edmonton four first male and five female runners had faster second half of the distance, in Boston six first men and two women, in Berlin three first men and none of women, in Athens all ten first and three first women. It means that the tactics of running differs for the first few runners at the finish and for the rest of the ten first runners (see Figure 2) and for many other runners. The highest velocity of a 5 km fragment had a winner of Athens marathon. This was due to the rather slow first half of a run. The last 2.2 km he ran with average velocity of 6.0 m/s.

Absolute accelerations during the run (velocity differences for 5 km fragments) were of the lowest values within the male group in Edmonton (the first ten achieved 0.000006 m/s^2) and the highest values within the female group in Edmonton (the first ten achieved 0.000092 m/s^2). Except of Edmonton for women and Athens for men all other marathons showed usually lower absolute accelerations for the first ten runners comparing to the rest runners.

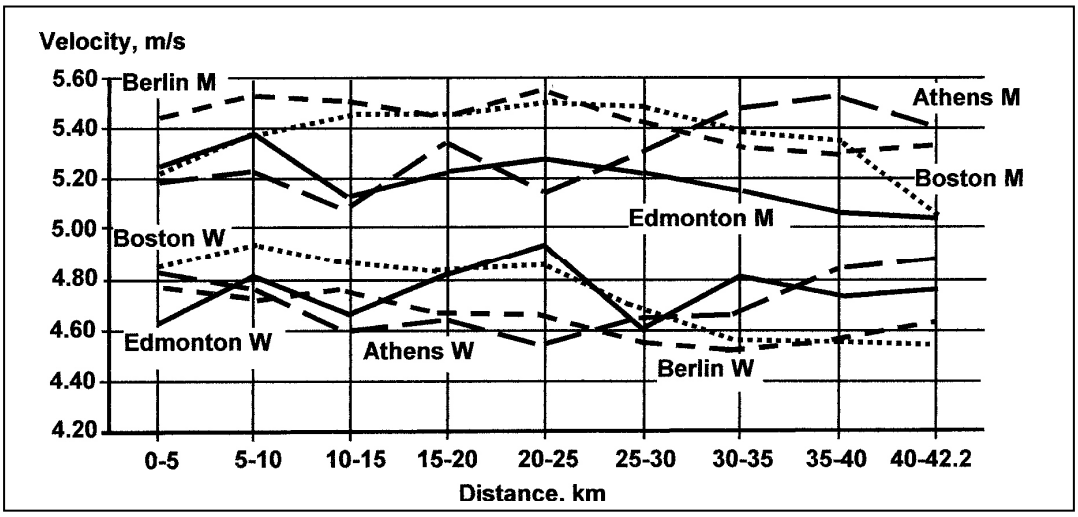

Figure 2: Mean velocities of 5 km fragments for ten first men (M) and women (W) in four marathons. Note that except of Athens and Edmonton (women) all other were started faster and ended slower, which is in contradiction to the best few runners at the finish. Fluctuation in velocity is, among other reasons, due to geometrical profile of the course (see Figure 1)

Taking into account index of velocity's deviation better female runners achieved bigger value of that index, while male runners achieved smaller value. Indexes of runners' endurance show runners, except of few first at the finish, had usually poor endurance. It must be said starting time which was so different as, e.g. in Edmonton for women at 08:00 and in Athens at 18:00, could have an influence on results obtained. Also very different temperature as, e.g. in Berlin as low as 14 ^{O}C and in Athens as high as 35 ^{O}C, had influence on results.

CONCLUSION:

Since huge amount of runners applies wrong tactics of running (they run too fast first fragments of the entire distance) they must be taught what tactics is optimal for them, i.e. what velocity they should have for particular run and for particular fragment of a run taking into account geometry of a course.

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