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# Kinematic Analysis of Runners in the 2011 Olympus Marathon

Giovanis V.<sup>1</sup> and Erdmann W.S.<sup>2</sup>

<sup>1</sup>National and Kapodistrian University of Athens, Athens, GREECE, EU <sup>2</sup>Sniadecki University of Physical Education and Sport, Gdansk, POLAND, EU

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# Abstract

Academic libraries exist to support the educational goals of their parent institution; one of such roles being to provide. This paper presents analysis of long distance running (44 km) in the 2011 Olympus Marathon in Greece, EU. The course consists of 21 km of an ascending leg (mean leaning angle of 7 degrees) and 23 km of a descending leg (mean leaning angle of 6 degrees). It starts at 3 m above the sea level, runs up to the summit at 2780 m and descends to the level of 320 m. From about 500 runners, the first 50 to reach the finish line were investigated. Their mean velocity over the whole course differed significantly, but the distribution of velocity along the whole course was similar for the 10 first runners at the finish, for runners from places 11 to 30 and for those from 31 to 50. It was anticipated that running uphill would be slower and running downhill would be faster, but the last fragment of the marathon (descending) was run with similar velocity to the first fragment (ascending). This was due to the level of fatigue experienced by the runners. Apart from the rest, the winner ran the last sector faster, as has been previously seen for other world level runners and for sportspersons in other long distance sport disciplines presented in other articles. The winner had an ascending mean velocity of 2.29 m/s, a descending mean velocity of 3.14 m/s and a mean velocity for the whole race of 2.67 m/s, with a standard deviation of 6 fragments equalling 0.576 m/s. Fluctuation of velocity (standard deviation/mean velocity) was smaller for better runners compared to the worse runners.

Keywords: Running, mountain marathon, kinematics, distribution of load, velocity.

# Introduction

People perform long time efforts for many reasons – at work, during military campaigns, and during recreation activities. Some of the most demanding activities are those dealing with rivalry in the form of sporting competitions.

During sport activities, one needs to take into account techniques of movement and tactics of performance. According to the Polish Sport Encyclopaedia<sup>1</sup>, sport tactics indicate the accomplishment of a sport performance where several problems are taken into account: rules of a sporting discipline, personal and rival skills, the sporting arena, and the conditions of a sporting rivalry. This is especially important during long distance running. The wrong running tactics can lead to exhaustion by the end of a race or failure to win a race and/or set a record time. There are numerous such examples where inappropriate tactics have left attempts to break a world or personal record unaccomplished. Some runners are unable to even complete a run, and are forced to abandon the race. One of the first such examples was described by Miller<sup>2</sup>. During the first modern Olympic Games held in Athens in 1896, runners who specialised in 1500 m also participated in a marathon. They started too briskly, leading the race for many kilometres. Spiridon Louis came to the leading position only when passing the 36th km and won the race. Those who led the run through the first half did not finish; from the 25 runners who assembled at the start, only nine appeared at the finish line.

Studies of Buman *et al.*<sup>3,4</sup> suggest that more than 40% of runners experience the exhaustion of physiological carbohydrate reserves (referred to as 'hitting the wall') during a typical marathon. Rapoport<sup>5</sup> says that the energetic constrains on endurance runners are subtle, and depend on several physiological variables, including muscle mass distribution, liver and muscle glycogen densities, and running speed.

In preparing a manner of running a particular training run, coaches discuss two values of a load with runners. One of those is a length of a distance, i.e. training volume (mechanical work). Costill<sup>6</sup> suggests that the training distances might be broken down weekly and in cycles of 4 weeks each. The greatest distance covered in a cycle should be in the second and fourth weeks. This means that, within a cycle, the total distance rises from shortest to longest data.

Along with the length of the distance, its profile is also very important. There are courses within the stadium that are totally flat. Those along the roads are of different but moderate elevations. They can be situated at the sea level or at the upland level, and there are also special courses which run along the hills and mountains.

The other load value is the time needed to cover a distance, although Fox *et al.*<sup>7</sup> suggest that little emphasis is placed on speed, which is based on time data, during the training of long

distance runs. Nevertheless, with work data and time data, one can obtain the training intensity (mechanical power).

Taking into account kinematics data, distance and time, one can calculate the velocity of a run. Comparing velocities of different values and time spent on changing velocity, one can calculate acceleration. Velocity and acceleration can be calculated as either instantaneous values or mean values as biomechanical quantities for all running distances.

Long distance running, especially marathon running, is a difficult performance. Those runners who distribute their effort poorly along the whole distance could finish the competition with a poor time, have to leave the track or even die trying. Erdmann and Lipinska<sup>8,9,10</sup> presented papers where they described the best tactics for running on a flat course; they indicated that the velocity of running should increase along the course and deviations from the mean velocity in different sectors should be minimised. This proper velocity distribution is also used in other sporting disciplines, e.g. in alpine skiing<sup>11</sup>, rowing<sup>12</sup>, swimming<sup>13</sup>, and cycling<sup>14</sup>.

**Concept of the research:** Running uphill and then downhill is a specific manner of load that has to be overcome. In particular, it is not easy to distribute a constant effort along the whole distance. Based on this, the main question was raised: how do athletes run such a specific mountain course over a marathon distance?

**The aims of our research were:** i. to assess the profile of the marathon course of the Olympus Marathon in Greece, EU (44 km), ii. to investigate manners of load distribution (through indirect quantity, i.e. velocity) along the course by runners, iii. to assess velocity according to the course's profile, and iv. to make recommendations for proper running tactics through the proper distribution of a load.

It was hypothesised that: i. the velocity downhill compared to the velocity uphill will always be higher; ii. velocity will change according to the angle of leaning of the mountain's slopes; and iii. better runners have different distributions of velocity compared to poorer runners.

**Detailed questions:** i. what is the uphill velocity of the runners? ii. What is the downhill velocity of the runners? iii. What deviations from the mean velocity of the whole distance do runners maintain? iv. What is the index of velocities using the comparison of uphill and downhill velocities? v. How do the best runners compare with those from lower finishing positions?

## **Material and Methods**

There were 518 runners (males and females) from 21 countries participating in the Olympus Marathon (26 June 2011); 448 (86%) of them finished the run (92% were male runners). In order to be eligible as a participant, each runner should have a given amount of points calculated according to a special

algorithm. This was introduced to guard against exhaustion. The running data of the first 50 runners to reach the finish line were taken into account.

The whole marathon distance was marked unevenly at every 2 to 6 km (13 marks). The markers at 10, 15, 21, 31, 37 and 44 km were chosen by the organising committee to show intermediate times of the runners. This yielded the following consecutive fragments: 10, 5, 6, 10, 6 and 7 km of the whole distance<sup>15</sup>.

Mean velocity, standard deviation, coefficient of variation, and velocity indices (velocity of the 2nd leg divided by velocity of the 1st leg) were calculated. The latter was calculated in absolute ("abs.vel.ix") and relative values, i.e. divided by the mean velocity ("rel.vel.ix") for every runner of the investigated group in order to analyse manner of load (velocity) distribution along the whole distance. Also, the cumulative mean velocity for selected runners was presented, i.e. mean velocity from the start to the consecutive marks of the distance. Correlation coefficients were calculated between S.D., rel.vel.ix and position at the finish line.

## **Results and Discussion**

**Results:** The Olympus Mountain, with the marathon course marked, is shown in figure-1 A. The course profile (figure-1 B) shows that the runners began at 3 m above sea level and reached the summit of 2780 m after 21 km of the ascending leg; they descended during the second leg of 23 km to the finish line at 320 m above sea level. The mean ascending angle equalled 7 deg. and mean descending angle equalled 6 deg.

The mean velocity of the entire course for the first runner was 2.67 m/s (mean uphill velocity 2.29 m/s, mean downhill velocity 3.14 m/s), for the runners placed between 1 and 10 was 2.46 (uphill 2.16 m/s, downhill 2.82 m/s); 11..30: 2.15 (uphill 1.88 m/s, downhill 2.48 m/s), and for those from 31 to 50 was 1.99 m/s (uphill 1.72 m/s, downhill 2.32 m/s). Mean velocity for the entire group of 50 runners equalled 2.15 m/s (uphill 1.87 m/s, downhill 2.48 m/s). There was significant difference in running velocity for the first ten runners at the finish line compared to the next 20 runners and an even greater difference between the first ten and the runners from places 31 to 50 (figure-2).

Looking at the velocities of fragments of distance one can see high fluctuations in velocity (figure-3). Standard deviation (for six velocity data) in absolute data for almost all runners had a value between 0.4 and 0.6 m/s. S.D. for the first runner was 0.576 (coefficient of variation 21.6), for the first 10 runners was 0.537 (21.7), for the runners from places 11 to 30 equalled 0.488 (22.7) and for the runners from places 31 to 50 equalled 0.478 (24.0). Therefore, the absolute values of standard deviation were higher for better runners compared to worse runners (figure-4 A) but in relative data (coefficient of variation) it was the reverse (figure-4 B). Research Journal of Physical Education Sciences . Vol. 1(1), 7-12, March (2013)

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Figure-1 Olympus Mountain, Greece, EU: A – general view with a course of the marathon run; B – profile of the course

## Runners 1..50



Figure-2 Mean velocities of the run for all 50 first runners at the finish.





Figure-3

Mean velocities for consecutive fragments of the course; runners 1..10 (diamonds), 11..30 (squares), 31..50 (triangles)

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Figure-4

Reversely proportional relationship (r = -0.401) between standard deviation of velocities and runners' place at the finish (A) and directly proportional relationship (r = 0.192) between coefficient of variation and runners' place at the finish (B). Although correlation coefficients are small they show tendency of relationship





Different approaches to running tactics in comparison to the runner no. 1 at the finish line (diamonds): A – improper approach to the run presented by runner no. 33 (squares, too high S.D.) and by runner 38 (triangles, too small S.D.); B – improper approach to the run presented by runner no. 10 (triangles, too high velocity at the beginning) and better approach of the runner no. 8 (squares, better distribution of velocity)

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There were different approaches to the running of several runners based on different distributions of velocity along the whole marathon course. These approaches were analysed according to the runner who was first to the finish line. For example, runner no. 33 at the finish had the highest standard deviation of velocity, while runner no. 38 had the lowest S. D. Both approaches were improper. For runner no. 33, the velocity between marks 31 and 37 was too high, while for runner no. 38 the velocity was too slow during the descending leg of the run (figure- 5 A). Runner no. 10 at the finish ran at the beginning with the winner, but then he ran much slower. Runner no. 8 ran slower at the beginning in comparison with runners 1 and 10, but with a better distribution of velocity; hence, he was better at the finish than runner no. 10 (figure-5 B).

Comparing velocities of the second leg (descending) with the first leg (ascending), the first three runners at the finish line had abs.vel.ix. of 1.37. There were many other runners who had this index below 1.3 (18 runners) or even below 1.2 (2 runners). Five runners had an abs.vel.ix above 1.4. They ran the 1st leg of the run too slowly and finished behind the first 30 runners. This

index should be kept at an optimal value between 1.2 and 1.4 (figure-6 A). On the other hand, the relative velocity index should be kept as small as possible. For the whole group the correlation coefficient between rel.vel.ix and place at the finish obtained a high value of r = 0.841 (figure-6 B).

**Discussion:** As has been shown for other marathon runs and for other sporting disciplines, there are different approaches of sportspersons according to the sporting event. The obtained results in this investigation revealed different distributions of velocity along the whole marathon course. Even though there was a difficult mountainous run, the tactics of running should be kept specific – similar to other long distance performances where the best runners, swimmers and representatives of other sporting disciplines achieve world or continental records.

It is not a good tactic to run too fast at the beginning of a run. This is valid, especially for lower level runners. On the flat course, the best runners used to attack the first leg with good velocity and the second leg with even better velocity.



Velocity indices: absolute velocity index (A) should be kept optimal and relative velocity index (B) should be kept as small as possible, but during mountainous run it bounds to the value of about 0.5.

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During the Olympus Marathon, the best ten runners, runners placed from 11 to 30 and those placed from 31 to 50 ran the second (descending) leg faster, but the last fragment was run with the same velocity as the first (ascending) sector. This was due to the high level fatigue at the end of the run. Nevertheless, it should be noted that the first runner to reach the finish line ran the last fragment with a higher velocity than the first fragment. This was the correct distribution of velocity during the run.

Fluctuation of velocity along the whole mountainous marathon run will not be close to zero, but it should be minimised. Better runners had much smaller fluctuations than worse runners.

### Conclusion

The aims of the investigations were achieved as planned. The first hypothesis was not proven as a whole. Although descending running was usually faster, for the majority of runners the last descending fragment was run with a similar velocity as the first ascending sector. As for the second hypothesis – in general, the angle of leaning of the mountain's slope was found to influence the velocity, but at the end of a run fatigue was seen to change this general view. The third hypothesis was proven as a whole – better runners have different distributions of velocity compared to poorer runners.

Answering the detailed scientific questions, it can be said that: i. while the first runner had an uphill mean velocity of 2.29 m/s, the entire group had a value that was lower by almost 20% (18.4%); ii. the first runner had a mean downhill velocity of 3.14 m/s and the whole group had a value that was lower by more than 20% (21.0%); iii. There were high deviations of velocity along the whole run – the standard deviation of velocity for the first runner was 0.576 m/s (coefficient of variation 21.60) and for the whole group it was 0.493 m/s (coefficient of variation 23.01); iv. The absolute velocity index for the majority of runners ranged between 1.2 and 1.4, but the relative velocity index had a strong relationship with the place of runners at the finish. The better the runner, the smaller the relative velocity index; and v. the best runners always have a higher velocity throughout the run.

Runners should be acquainted with the profile of the mountainous run in order to prepare proper tactics for running. Long distance running needs to be performed where it is applicable, with ascending lines of velocity values and with small values of velocity fluctuation.

#### References

- 1. Hadzelek K., (ed.) *Small encyclopedia of sport* (in Polish), Warsaw: Sport and Tourism (1986)
- 2. Miller D. *The official history of the Olympic Games and the IOC. Athens to Beijing, 1894-2008.* Translated to Polish, Poznan, Poland: REBIS Publishing House (2008)

#### Res. J. Physical Education Sci.

- 3. Buman M.P., Brewer B.W., Cornelius A.E., Van Raake J.L. and Petitpas A.J., Hitting the wall in the marathon: Phenomenological characteristics and association with expectancy, gender, and running history, *Psychol Sport Exerc*, 9, 177-190 (2008)
- 4. Buman M.P., Brewer B.W., Cornelius A.E., A discrete-time hazard model of hitting the wall in recreational marathon runners, *Psychol Sport Exerc.* **10**, 662-666 (**2009**)
- 5. Rapoport B.I., Metabolic factors limiting performance in marathon runners, PLoS *Comput Biol* 6(10):e1000960. doi:10.1371/journal.pcbi.1000960 (2010)
- 6. Costill D.L., Scientific bases of long distance training (in Polish), *Sport Wyczynowy (Competetive sport)*, 9, 1-76 (1976)
- Fox E.L., Bowers R.W., Foss M.L., *The Physiological Basis of Physical Education and Athletics*. (4th ed.). Philadelphia, Penn.: Saunders College Publishing (1988)
- Erdmann W.S. and Lipinska P. Kinematics of marathon running's tactics. Part one: course profile. In Schwameder, H., Strutzenberger, G., Fastenbauer, V., Lindinger, S., Muller E. (eds.) XXIV International Symposium on Biomechanics in Sports. Proceedings, 2, 689-692 (2006)
- 9. Lipinska P., *Kinematic Quantities and Geometry of a Course and Tactics of Marathon Run* (in Polish). Doctoral dissertation, Gdansk: J. Sniadecki University of Physical Education and Sport (2006)
- Lipinska P. and Erdmann W.S., Kinematics of marathon running. Part two: distribution of velocity. In H. Menzel, and M.H. Chagas (eds.) XXV International Symposium on Biomechanics in Sports, Proceedings 483-486 (2007)
- Erdmann W.S., Giovanis V. Investigations on kinematics of giant slalom's tactics in alpine skiing. In: Miyashita M., Fukunaga T. – eds. *Proceedings, XVI Congress of the International Society of Biomechanics* (79), Tokyo: University of Tokyo (1997)
- Erdmann W.S., Urbanski R. Investigation of tactics of Olympic Games Sydney 2000 men rowing crews based on velocity of boats. In: Blackwell J.R. (ed.) *Proceedings, XIX Symposium of the International Society of Biomechanics in Sports. Works in Progress* (5). San Francisco: University of San Francisco (2001)
- Erdmann W.S. Kinematics of Tactics of men's 1500 m Freestyle Swimming at 2008 U.S. Olympic Team Trials Finals. *Research Yearbook. Studies in Physical Education and Sport* (currently name: *Baltic Journal of Health and Physical Activity*), 14(2), 92-98 (2008)
- 14. Wrzosek P. Analysis of tactics of individual running of a course of Road Bicycle Championships in Mendrisio 2009, Melbourne 2010, Copenhagen 2011 (in Polish). Master Thesis, Gdansk: Sniadecki University of Physical Education and Sport (2012)
- 15. www.olympus-marathon.com; accessed: 30 Aug (2011)