Biomechanical analysis of the medalists in the 10,000 metres at the 2007 World Championships in Athletics

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ABSTRACT

The aim of this study was to examine the biomechanical characteristics of the running motion of some of the world's top distance runners by observing the top three placers in the men's 10,000m final at the 2007 IAAF World Championships in Athletics in Osaka. The athletes studied showed few fatigue symptoms and only slight changes in average running velocity and running motion throughout most of the race. The winner, Bekele (ETH) showed greater mean power and lower effectiveness of mechanical energy utilisation to running velocity, however he increased this effectiveness at the end of the race. There were differences in the maximum, minimum and range of the thigh and shank angle between the runners studied and these did not vary greatly throughout the race. The maximum thigh angular velocity of the recovery leg, which might be a critical motion for distance runners, increased in Bekele. To be successful at the highest level a distance runner must be able to maintain high running velocity throughout the race and then sprint much like a sprinter. The authors conclude that it is therefore necessary not only to utilise mechanical energy efficiently but to have the capacity to generate greater mechanical energy when necessary.

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Introduction

An important task for success in distance running is to maintain running velocity over the entire race distance. However it is not unusual for the winner and second place in top-level races to be separated by a second or less. Therefore skilful race management is also a very important success factor. In recent Olympic and World championship finals, the winners have, in addition to keeping a high average velocity,

Table 1: Personal details of the medallists in the men's 10,000m at the 2007 World Championships in Athletics

Place	Athlete	Height (m)	Weight (kg)	Osaka Result	Personal Best
1	Bekele (ETH)	1.60	54	27:05.90	26:17.53
2	Sihine (ETH)	1.71	55	27:09.03	26:39.69
3	Mathathi (KEN)	1.67	52	27:12.17	27:08.42

made use of two highly effective strategies: (1) changing running velocity intentionally throughout the race to cause rivals to use energy; (2) increasing running velocity sharply on the last lap, finishing much like a sprinter.

From an energetic viewpoint, both the increase in energy generation and the effective utilisation of energy to generate running velocity are critical performance factors for distance runners. Physiological studies have revealed the relationship of factors such as VO_2max, lactate threshold and running economy to distance running performance. However, in most of these studies, the evaluations of VO_2max and running economy have been made from treadmill tests in a laboratory.

Biomechanical studies can indicate the direct relationship of the running motion to race performance. ENOMOTO et al. (1997) suggest that elite distance runners show a higher effectiveness of mechanical energy utilisation to running velocity in a running cycle. One of the most interesting aspects of distance running is how well the athletes are able maintain running velocity in the face of increasing fatigue. ELLIOT & ACKLAND (1981) showed the changes in kinematic variables during the race that are a result of fatigue. WILLIAMS et al. (1991) suggest that changes in running motion due to fatigue are different from individual to individual. However, there are few studies about changes in running motion in the world's top distance runners during a race. More studies of this type might give useful information about the running techniques of successful runners and new insight into training for distance races from a biomechanical viewpoint.

The aim of this study was to examine the biomechanical characteristics of the running motion of some of the world's top distance runners by observing the top three placers in the men's 10,000m final at the 2007 IAAF World Championships in Athletics in Osaka.

Methods

We videotaped the runners at a fixed area on the backstretch during the men's 10,000m final at the 2007 World Championships in Athletics using two digital video cameras (60Hz), one from the side and one giving a front view of the runners, in order to make the motion analysis. Another video camera followed the lead group for the entire race and using this recording we were able to calculate the split time for each 100m.

Running velocity and stride frequency were derived from the time for each 100m and the average time of a cycle (two strides) in each 100m. Stride length was obtained by dividing running velocity by stride frequency.

The running motion of the top three finishers in the race was analysed for a running cycle at five stages in the race: 600m (Stage 1), 3800m (Stage 2), 6200m (Stage 3), 8200m (Stage 4) and 9400m (Stage 5). The three-dimensional motion analysis technique was used.

After calculation of the three-dimensional coordinates and smoothing the coordinate data using a digital Butterworth filter, the centre of mass of the body, angles and angular velocities of the segments and joints of the lower limbs, and the mechanical energy of the whole body were calculated. The effectiveness index of mechanical energy utilisation to running velocity was calculated by horizontal translational mechanical energy of the body divided by mechanical work in a cycle (ENOMOTO et al., 1997), which was calculated from the sum of the energy change of each segment in each time interval (METZLER et al., 2002).

Results & Discussion

The first place finisher of the race was Kenenisa Bekele (ETH), the world record holder for the 10,000m, the second place finisher was Sileshi Sihine (ETH) and the third place finisher was Martin Irungu Mathathi (KEN). Bekele's winning time was among the top 100 times in history (and his season best time at that point) despite the high temperature (30°C) and humidity (65%) in Osaka that night. Personal details for the three medallists are given in Table 1.

Table 2 shows the split and segment times for each 1000m for the three athletes studied. In the first nine kilometres, the splits were almost the same for each of the three and at 9000m they were all together. There were, of course, differences in the times for the last 1000m but even these were relatively small. The leaders suddenly sped up at around 8800m mark. Bekele was behind Mathathi

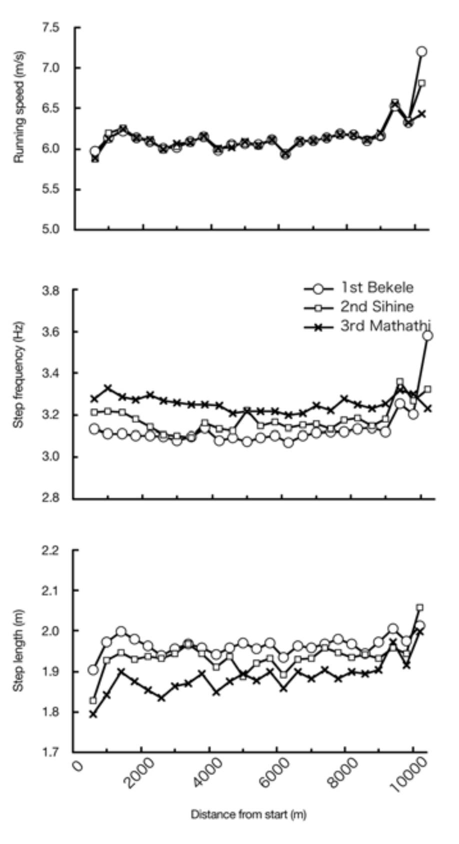

Figure 1: Average running velocity, stride frequency and stride length in each 400m of the race

Table 2: Split and segment times for each 1000m of the race

Distance	1. Kenenisa Bekele (ETH) Split time	Segmenet time	2. Sileshi Sihine (ETH) Split time	Segment time	3. Martin Irungu Mathathi (KEN) Split time	Segment time
1000	2:44.36		2:44.53		2:45.38	
2000	5:27.61	2:43.25	5:27.79	2:43.26	5:28.19	2:42.81
3000	8:13.59	2:45.98	8:13.79	2:46.00	8:14.04	2:45.85
4000	10:58.21	2:44.61	10:58.36	2:44.56	10:58.36	2:44.31
5000	13:43.41	2:45.20	13:43.62	2:45.27	13:43.76	2:45.40
6000	16:29.22	2:45.82	16:29.39	2:45.77	16:29.52	2:45.77
7000	19:13.07	2:43.85	19:13.32	2:43.93	19:13.37	2:43.85
8000	21:55.20	2:42.13	21:55.42	2:42.10	21:55.53	2:42.16
9000	24:35.79	2:40.59	24:35.96	2:40.54	24:35.54	2:40.01
10000	27:05.90	2:30.11	27:09.03	2:33.07	27:12.17	2:36.63

and Sihine and seemed to be beaten, but he sped up dramatically on the final lap and left the others behind. The times for the final lap were 55.51 for Bekele, 58.66 for Sihine and 62.16 for Mathathi.

Figure 1 shows the average running velocity, stride frequency and stride length in each 400m for the athletes studied. There was little change in stride frequency or stride length until 9000m. ELLIOT & ACKLAND (1981) showed that a decrease in running velocity is caused by a decrease in stride frequency, while WILLIAMS et al. (1991) reported that runners show a decrease in stride length running at the same speed under fatigue conditions. The data from this race showed no significant change in the support times (average of right and left foot) during the race. It seems that the top three ran as if they were not fatigued throughout the race despite the hot muggy conditions.

Bekele showed a low stride frequency and large stride length, conversely Methathi showed a high stride frequency and small stride length. The average stride length to body height were 1.23, 1.13 and 1.13 for Bekele, Sihine and Mathathi, respectively. Bekele increased his running velocity by increasing stride frequency greatly in the final lap. Correlation coefficients of running velocity to stride frequency and stride length were 0.904 and 0.662 for Bekele, 0.753 and 0.492 for Sihine, and 0.377 and 0.717 for Mathathi. These results suggested that Bekele could maintain a large stride length during the race and change his running velocity by changing stride frequency, especially in the final sprint.

Figure 2 shows the changes in the effectiveness index of mechanical energy utilisation to running velocity (EI) and mean power, which was calculated by dividing mechanical work by cycle time in Stages 1 to 5. The EI of Bekele was smaller than the others in stage 1, it then increased in Stages 3 and 5. The EI of both Sihine and Mathathi was greater than Bekele in stage 1, but Sihine decreased his from Stage 4 to 5. Mathathi maintained his EI throughout the race.

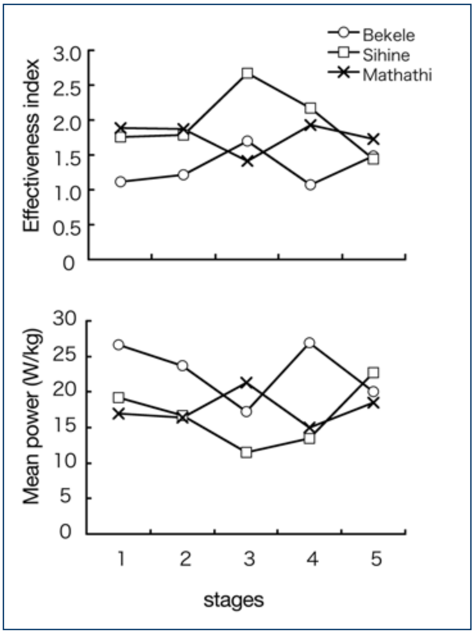

Figure 2: Changes in the effectiveness index of mechanical energy and mean power

The mean power was not consistent throughout the race. Bekele's mean power was greater than the others in stages 1 and 2. These results suggest that the running motion of Bekele requires more energy but he increased his effectiveness to maintain running velocity and then speed up at the end of the race. Mathathi may have a good running technique to utilise mechanical energy effectively, but he was not able to output more energy in order to speed up at end of the race.

Figure 3 shows the changes in the maximal and minimum thigh and shank angles for the athletes studied. The thigh and shank angle was defined as the angle to the vertical (counter-clockwise is positive). Positive means swinging to the front of the body and negative means backward swing. The length of each bar indicates the range of motion of the thigh and shank. The range of shank movement for Bekele was greater than for the others, and the range of thigh movement for Mathathi was greater than for the others. All three runners showed minor changes in maximum and minimum angles of thigh and shank. The maxi-

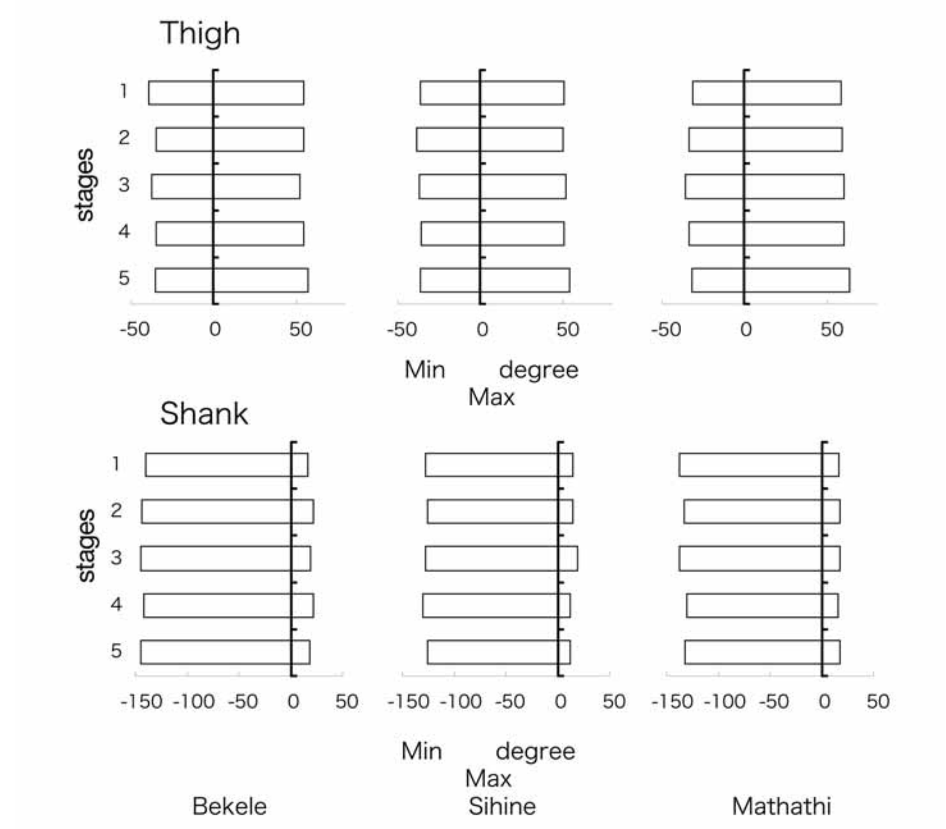

Figure 3: Maximum and minimum angles of the thigh and shank

mum thigh angle and the range of movement of the thigh for Mathathi gradually increased, while those of Bekele and Sihine did not change. The maximum and minimum shank angles were maintained by Bekele but decreased for Sihine and Mathathi.

Figure 4 shows stick pictures of the movement of the three athletes at the 8200m mark (Stage 4) in the race. The thin lines indicate the left side. The pictures for Bekele shows that his shank was pulled up to the thigh greatly in the early recovery phase, with the consequence of a decrease in minimum knee angle, and then swung forward greatly before the foot strike.

Figure 5 shows the changes in the maximum thigh angular velocity (MTAV). In stages 1 and 2, Mathathi showed a greater MTAV than the others. Bekele showed a gradual increase in MTAV from stages 1 to 4. These results imply that Bekele maintained the forward swing velocity of the thigh as a result of his control of the shank motion, which might be characteristic for Bekele. ENOMOTO & AE (2005) suggest that Kenyan runners swung the thigh forward faster due to great flexing of the knee of the recovery leg and that forward swing of the thigh is an important motion for distance runners.

In conclusion, three of the world's top distance runners competing in the 10,000m at the 2007 IAAF World Championships in Athletics in Osaka showed only slight changes in running motion and few fatigue symptoms, despite difficult climatic conditions.

Figure 4: Stick pictures of the athletes' movement at the 8200m mark (stage 4) in the race

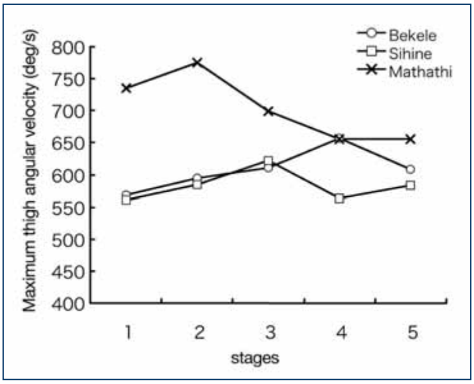

Figure 5: Change in maximum thigh angular velocity

The outstanding characteristic of the winner Bekele's running motion was a greater shank motion, which requires the expenditure of more mechanical energy. For distance runners to maintain a high running speed during a race and to sprint at the end, it is necessary to not only utilise mechanical energy efficiently but also to be able, much like sprinters, to generate greater mechanical energy when necessary.

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