Initial findings of a biomechanical analysis at the 2008 IAAF World Race Walking Cup

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ABSTRACT

The purpose of this study was to examine the walking techniques of the top finishers in the three senior races at the 23rd IAAF World Race Walking Cup in Cheboksary, Russia. Each race was videoed with two cameras placed at the side of the course where the athletes passed on every lap. Analysis was made of the top eight 20km women, top eight 50km men, and the third to 10th place finishers in the men's 20km. The results showed that a balance between maintaining a long stride length and a high stride frequency was crucial in achieving success. Because of the limitations imposed by IAAF Rule 230, the hip and ankle muscles must have the requisite power and endurance to develop and maintain high speeds. Men and women differ in the amount of rotation that occurs at the hips and shoulders. Men are able to attain longer strides by moving their hips through larger ranges of movement. In contrast to the joint angles of the legs, there was a large variation in the angles of the shoulders and elbows. It is advisable for athletes to concentrate on maintaining efficient technique in training and in competition.

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Introduction

A number of research studies have analysed race walking but few if any have evaluated the techniques of the world's very best walkers. The provision of such biomechanical information is invaluable for understanding how success is achieved at the highest level. The best means by which elite athletes are analysed is in competition. The aim of this study was to analyse athletes at the 23rd IAAF World Race Walking Cup held at Cheboksary, Russia, in May 2008. The event was a particularly successful showpiece of elite race walking, and the initial findings of the study presented here concentrate on the top finishers in the women's 20km, men's 20km and men's 50km races.

The Cheboksary course, built specifically for race walking, was a completely flat 2km route with fast turns and long straight stretches. The nature of the course and favourable weather conditions resulted in many athletes recording national records and personal bests. A new world record was set in the men's 50km event, as well as championship records in both the men's and women's 20km events.

Methods

Two digital cameras (50Hz) were placed at the side of the course at approximately 45º and 135º to the plane of motion respectively. The reference volume was 5.2m long, 2m wide, and 2m high; this ensured data collection of at least three successive steps and provided a calibration reference for 3D-DLT. The cameras were set up at the 200m point of the 2km lap. The 20km men and women were analysed as they passed through 14.2km, as up to this point the leading twelve men had remained together in a group. The 50km men were analysed as they passed 28.2km. These athletes were very much spread out by this point.

The top eight finishers in both the women's race and the men's 50km race were analysed and their results reproduced here. Because it was not possible to analyse the gold and silver medallists from the men's 20km race due to obstructed views, the results of the men finishing third to 10th have been analysed instead. The video data were digitised using motion analysis software (SIMI, Munich). The recordings were smoothed using a Butterworth 2nd order low-pass filter, and DE LEVA's (1996) body segment parameter models for males and females were used to obtain centre of mass data. Details of each athlete analysed are included in Tables 1a – c.

Variables of interest were defined as follows:

- Speed: the average horizontal speed during one complete gait cycle (two steps).
- Stride length: the distance the body travelled between a specific phase on one leg and the same phase on the other leg.
- Stride frequency: measured by dividing horizontal speed by stride length.
- Hip/shoulder rotation: the horizontal plane movements of the pelvic girdle/shoulders associated with race walking.

Definitions of specific reference points used in this study are as follows:

- Initial contact: the first visible point during stance where the athlete's foot clearly contacts the ground.
- Toe-off: the last visible point during stance where the athlete's foot clearly contacts the ground.
- Mid-stance: the point where the athlete's foot was directly below their body's centre of mass, used to determine the 'vertical upright position' (IAAF Rule 230.1).
- Foot ahead: the distance from the centre of mass of the landing foot to the body's overall centre of mass.
- Foot behind: the distance from the centre of mass of the toe-off foot to the body's overall centre of mass.

Results and Discussion

The walking speeds, stride lengths and stride frequencies of the 20km women, 20km men and 50km men are shown in Tables 2a, 2b and 2c respectively. The 20km men were more than 1.5km/hr faster than both groups on average, but the 20km women and 50km men had similar speeds. The 20km men had the longest steps and the 20km women the highest stride frequencies – this is an expected result due to the differences in height and consequently leg length.

Table 1a: 20km women participants, ages (yrs), heights (m) and performances

Place	Athlete	Age	Height	Time	Additional comments
1	Kaniskina (RUS)	23	1.60	1:25:42	2008 Olympic Champion
2	Sibileva (RUS)	27	1.60	1:26:29	
3	Santos (POR)	25	1.64	1:28:17	Personal Best
4	Arkhipova (RUS)	29	1.64	1:28:29	
5	Vasco (ESP)	32	1.57	1:28:39	2000 Olympic bronze
6	Loughnane (IRL)	32	1.63	1:29:17	Personal Best
7	Saville (AUS)	33	1.64	1:29:27	2004 Olympic bronze
8	Poves (ESP)	30	1.68	1:29:31	Personal Best

Table 1b: 20km men participants, ages (yrs), heights (m) and performances

Place	Athlete	Age	Height	Time	Additional comments
3	Sánchez (MEX)	21	1.76	1:18:34	Personal Best
4	Markov (RUS)	35	1.74	1:19:04	1999 World Champion
5	Krivov (RUS)	22	1.85	1:19:10	
6	Tysse (NOR)	27	1.90	1:19:11	National Record
7	Adams (AUS)	31	1.89	1:19:15	Personal Best
8	Molina (ESP)	29	1.73	1:19:19	2002 European bronze
9	Heffernan (IRL)	30	1.70	1:19:22	National Record
10	Tallent (AUS)	23	1.78	1:19:48	2008 Olympic double medallist

Table 1c: 50km men participants, ages (yrs), heights (m) and performances

Place	Athlete	Age	Height	Time	Additional comments
1	Nizhegorodov (RUS)	27	1.74	3:34:14	World Record
2	Schwazer (ITA)	23	1.85	3:37:04	2008 Olympic Champion
3	Nymark (NOR)	31	1.80	3:44:59	2006 World Cup silver
4	Odriozola (ESP)	34	1.78	3:47:30	
5	Nava (MEX)	26	1.76	3:47:55	Personal Best
6	Kirdyapkin (RUS)	27	1.78	3:48:29	2005 World Champion
7	Höhne (GER)	30	1.85	3:49:03	
8	De Luca (ITA)	26	1.88	3:49:21	

In the 20km women's race, Kaniskina finished almost fifty seconds clear of Sibileva, and two and a half minutes ahead of Santos. Her dominance was achieved by having the longest stride length; as a percentage of height this was the second highest of all the twenty-four athletes studied. Most of the women had similar stride frequence, ranging between 3.34 and 3.47Hz. The shortest athlete, Vasco, had by far the highest frequency but a stride length 6cm less than the average. Her stride frequency, 3.72Hz, corresponds to just over 223 steps per minute. Vasco was the second-fastest woman measured at this

Table 2a: Speed, stride length and stride frequency – 20km women

Athlete	Speed (km/hr)	Stride length (m)	Stride length (%)	Stride Frequency (Hz)
Kaniskina	14.79	1.19	74.1	3.47
Sibileva	13.75	1.10	69.0	3.46
Santos	13.89	1.16	70.5	3.34
Arkhipova	13.58	1.12	68.6	3.35
Vasco	14.19	1.06	67.5	3.72
Loughnane	13.80	1.11	68.4	3.44
Saville	13.22	1.06	64.7	3.46
Poves	13.37	1.08	64.0	3.45
Mean	13.82	1.12	68.4	3.46
SD	0.50	0.04	3.2	0.12

Table 2b: Speed, stride length and stride frequency – 20km men

Athlete	Speed (km/hr)	Stride length (m)	Stride length (%)	Stride Frequency (Hz)
Sánchez	15.77	1.24	70.3	3.54
Markov	15.68	1.29	74.4	3.37
Krivov	15.42	1.36	73.4	3.16
Tysse	15.09	1.29	68.1	3.24
Adams	14.93	1.26	66.6	3.30
Molina	15.79	1.27	73.6	3.44
Heffernan	15.34	1.23	72.5	3.46
Tallent	15.19	1.22	68.6	3.45
Mean	15.40	1.27	70.9	3.37
SD	0.32	0.04	2.9	0.13

Table 2c: Speed, stride length, and stride frequency – 50km men

Athlete	Speed (km/hr)	Stride length (m)	Stride length (%)	Stride Frequency (Hz)
Nizhegorodov	14.52	1.20	69.2	3.35
Schwazer	14.28	1.23	66.5	3.22
Nymark	13.76	1.16	64.5	3.29
Odriozola	13.11	1.12	62.8	3.26
Nava	13.54	1.17	66.3	3.22
Kirdyapkin	14.23	1.22	68.3	3.25
Höhne	13.33	1.24	67.0	2.99
De Luca	13.39	1.22	65.1	3.04
Mean	13.77	1.19	66.2	3.20
SD	0.52	0.04	2.1	0.12

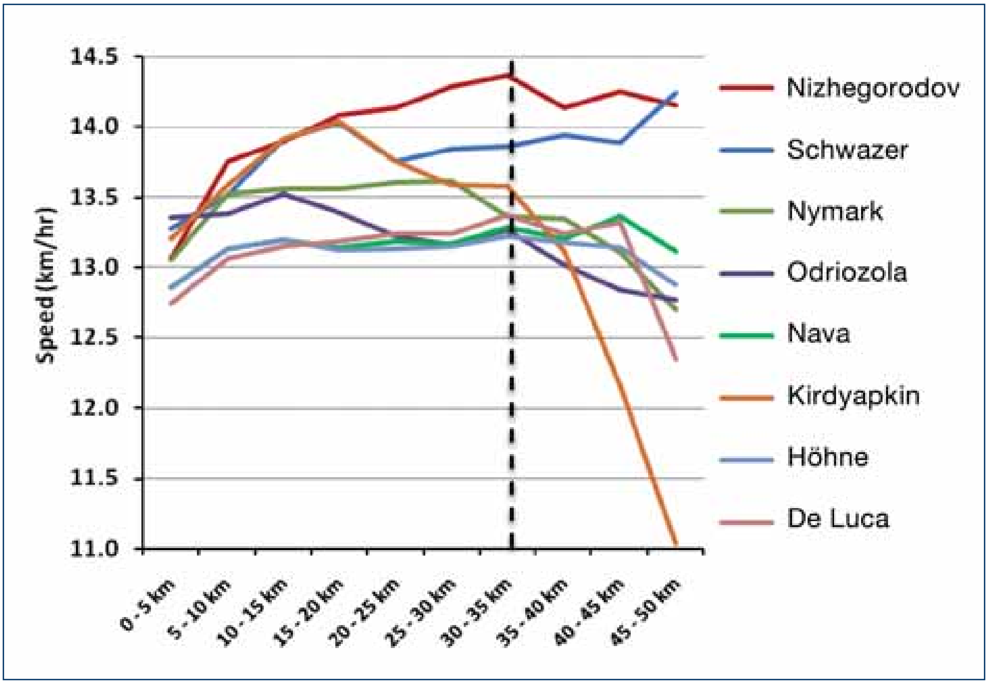

Figure 1: Average 5km interval speeds of the top eight 50km finishers

point and emphasises the equal importance of stride frequency and stride length.

In the men's 20km race, only 18 seconds separated the athletes finishing 4th to 9th. At the point of measurement, the five fastest athletes were Molina, Sánchez, Markov, Krivov, and Heffernan in that order. Interestingly, all five had stride lengths greater than 70% of their standing heights. Their actual stride lengths ranged from 1.23 to 1.36m. Krivov had by far the longest steps but also the lowest stride frequency. It is possible he experienced overstriding and a reduction in stride length would actually have been of overall benefit.

The 50km event is as much about endurance as technique and speed. Figure 1 shows the average speeds for each 5km section for each of the top eight finishers. The black dashed line placed at the 30 – 35km mark represents the point at which most athletes started to slow down due to fatigue. Nizhegorodov managed to maintain his speed at a reasonably constant level, with slight deceleration towards the very end. Schwazer, who won Olympic Gold three months later, actually sped up after this point. Nizhegorodov had both the longest stride length (%) and the highest stride frequency; two of the tallest athletes, Höhne and De Luca, had the lowest stride frequencies.

The distances of the foot ahead and behind the centre of mass, as well as rotation values for the hips and shoulders, are shown in Tables 3a, 3b, and 3c. Both foot ahead and foot behind distances are expressed as a percentage of the athletes' heights in order to allow easier comparison.

Kaniskina was quite different from all the other athletes. Her foot landed further in front of her and her toe-off distance was also greater. Although a landing foot too far in front of the body can act as a brake and slow the athlete (LAFORTUNE et al., 1989), she was

Table 3a: Relative distances to the foot and rotation values – 20km women

Athlete	Foot ahead (%)	Foot behind (%)	Hip rotation (°)	Shoulder rotation (°)	Distortion angle (°)
Kaniskina	22.5	28.8	15	25	35
Sibileva	20.6	28.1	20	24	42
Santos	21.3	28.0	24	20	39
Arkhipova	21.3	26.2	21	16	36
Vasco	19.7	28.0	15	19	34
Loughnane	18.4	26.4	23	20	41
Saville	19.5	25.6	13	19	30
Poves	18.5	25.0	10	22	31
Mean	20.2	27.0	18	21	36
SD	1.5	1.4	5	3	4

Table 3b: Relative distances to the foot and rotation values – 20km men

Athlete	Foot ahead (%)	Foot behind (%)	Hip rotation (°)	Shoulder rotation (°)	Distortion angle (°)
Sánchez	21.0	26.1	26	16	40
Markov	21.3	27.0	18	15	32
Krivov	21.6	27.6	23	16	37
Tysse	20.5	28.4	22	15	36
Adams	20.1	24.9	25	14	38
Molina	19.1	27.7	20	14	30
Heffernan	21.8	27.1	23	19	42
Tallent	21.3	25.3	24	14	36
Mean	20.8	26.8	23	15	37
SD	0.9	1.2	3	2	4

able to overcome this potential disadvantage when lengthening her stride. In fact, the distance of the foot ahead tended to increase with higher racing speeds in all the women studied.

A similar pattern arose with the foot behind distance, which itself also allows for greater stride lengths (HOGA et al., 2003). There was less variation in both foot ahead and foot behind distances for the 20km and 50km men. It should be remembered that these race walkers are world class and have the muscular strength to overcome potentially slow techniques that weaker athletes do not.

Although women in general have wider hip structures, the results show that hip rotation averages were in fact lowest in this group while the highest found were in the 50km men. By contrast, the women had the highest values for rotation of the shoulders. Increased hip rotation allows for greater functional step lengths (MURRAY et al., 1983). Women race walkers should be aware that improving their range of hip rotation will increase walking

Table 3c: Relative distances to the foot and rotation values – 50km men

Athlete	Foot ahead (%)	Foot behind (%)	Hip rotation (°)	Shoulder rotation (°)	Distortion angle (°)
Nizhegorodov	21.8	28.2	28	18	45
Schwazer	21.8	27.1	22	17	39
Nymark	21.1	27.0	27	18	43
Odriozola	20.0	25.6	31	17	48
Nava	21.9	24.2	28	13	41
Kirdyapkin	21.6	27.8	29	20	48
Höhne	21.9	26.4	28	14	41
De Luca	21.1	26.5	23	15	36
Mean	21.2	26.4	27	17	43
SD	0.8	1.3	3	2	5

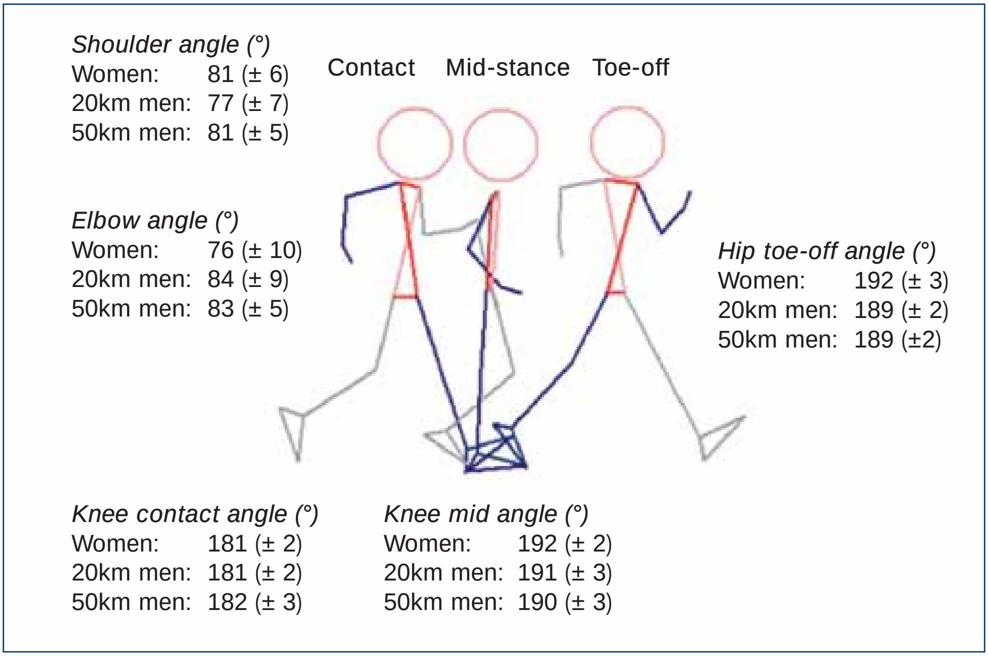

Figure 2: Joint angle measurements for each group of athletes (The darker lines indicate the right side of the athlete, but all measurements are averages of both sides.)

speed by allowing greater stride lengths. The main function of the rotation of the shoulders is in counterbalancing the movement of the hips, and greater upper body strength will improve the control of this rotation.

The hip-shoulder distortion angle is also shown. This is a measure of the amount of torsion in the trunk caused by these rotations of hips and shoulders (KNICKER & LOCH, 1990); the angle is calculated by summing the two values at a given instant. For some athletes, maximum hip and shoulder rotations were simultaneous (e.g. Vasco, Heffernan) but for most the maximum values occurred a short time apart. The 20km athletes had less time per stride to move through such large ranges of motion and the greater distortion angles of the 50km men are possibly related to their lower cadences.

Key angular measurements are shown in Figure 2. Of these, the angle of the knee at both contact and mid-stance are the most important because of the requirements of IAAF rule 230.1. In each group the average was above 180°; nine of the 24 athletes had values below this (ranging from 177° to 179°). Seven of these received either a caution or warning for bent knees at some point. All athletes had hyperextended knees by mid-stance.

The hip joint angles of 189° for men and 192° for women are 9 and 12° of hip hyperextension respectively. The slightly greater hyperextension in women may have compensated for their lower pelvic rotations and allowed small increases in stride length. With both hip and knee angles there is little variation found between athletes, even those of different genders competing over different distances. However, the data on rotation of the shoulders and hips show that in the upper body there is a great deal of variation and identifying the optimum movement in these joints is more difficult.

The shoulder angles in Figure 2 are measures of the maximum amount of shoulder hyperextension that occurred at or just before foot contact (on the same side of the body). This movement is associated with flexion of the hip joints. The women and the 50km men have the same average angle, but the 20km men have slightly lower values. The elbow angles at mid-stance have been provided as a point on technique; an angle of 90° has been recommended by coaches (e.g. MARKHAM, 1989) but the average values here are slightly lower. A large range was found, particularly for the women; the two Spanish athletes, Vasco and Poves, had elbow angles of only 68° at this point.

In conclusion, the world's best athletes are able to achieve great walking speeds with considerable stride lengths and high stride frequencies. This was also shown in our previous study at the European Cups which itself featured many world-class performers. The very best are able to balance these two factors – training to achieve this is crucial. There are differences between men and women, related to body shape and size; and between 20km and 50km walkers, related to the need for strict pace judgement in the longer race. Although all these athletes and their performances are world-class, it is clear that there are large variations in technique and it is unwise to assume that any particular athlete's technique is optimal.

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