A Biomechanical Analysis of World-Class Senior and Junior Race Walkers

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ABSTRACT

The purpose of this study was to conduct a biomechanical analysis of all 15 medallists at the 25th IAAF World Race Walking Cup in Saransk, Russia. Each of the medallists was videoed during the faster second half of the race. Two cameras were placed alongside the course and 3D analysis of the video data conducted in order to measure the most important variables in race walking. As expected, stride length correlated with velocity, and data on individual athletes emphasised the importance of this variable. However, longer strides were negatively associated with stride frequency, and so a balance between these two fundamental variables is advisable. The athletes adhered very closely to the race walking rule with regard to having a straightened knee at first contact; however, they were closer to the threshold of visibly losing contact. While there was little variation between athletes in terms of hip and knee angles, there were larger variations found within the measurements of shoulder and elbow angles. Coaches and athletes should be mindful that race walking is a whole-body activity and inefficient movements should be identified and corrected as appropriate.

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Introduction

Race walking is part of the athletics programme at the Olympic Games and all other major athletics championships. Championship competitions are held over 20km for men and women, and 50km for men only. Races for junior men and women (under 20 years of age) are held over 10km. The IAAF World Race Walking Cup is a biennial event intended primarily as a team competition between IAAF member nations; however, athletes also compete as individuals. The World Cup is seen as a measure of each competing nation's depth of talent[1]. As nations are allowed up to five entries per senior race, the participating numbers are relatively high compared with the more prestigious World Championships and Olympic Games. This results in an overall greater depth in talent as strong nations can enter more athletes than in the more exclusive championship races, and thus the World Cup is a highly regarded competition amongst the leading race walking nations[2,3].

Camera position relative to the course. The location was at approximately the 500m point of the 2km lap.

While it is very useful to measure biomechanical variables across large groups of athletes[4,5], it is equally valuable to focus on performances of the very best athletes in understanding the determinants of fast race walking. The aim of this study was to analyse the top three finishers in each race at the 25th World Race Walking Cup held in Saransk, Russia, in May 2012.

Methods

Two Canon digital camcorders (50 Hz) were placed at the side of the course at approximately 45° and 135° to the plane of motion respectively. The reference volume used was 5.2m long, 2m wide, and 2m high; this ensured data collection of at least three successive strides and provided a calibration reference for 3D-DLT. The cameras were set up at approximately the 500m point of the 2km lap. The 20km men and women were analysed as they passed through 14.5km, while the 50km men were analysed as they passed 28.5km. Both sets of junior athletes were analysed as they passed through 6.5km.

The top three finishers in all five races were analysed and their results are reproduced here. The video data were anlaysed using motion analysis software (SIMI, Munich). Variables and gait events of interest were defined as follows:

- Velocity – the average horizontal velocity during one complete gait cycle,
- Stride length – the distance the body travelled between a specific phase on one leg and the same phase on the other leg,
- Stride length difference – the difference in length between right-to-left and left-to-right strides,
- Stride frequency – the number of strides taken per second, measured in hertz (Hz),

- Contact – the first visible point during stance where the athlete's foot clearly makes contact with the ground,
- Toe-off – the last visible point during stance before the athlete's foot clearly loses contact with the ground,
- Midstance – 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).

DE LEVA's[6] body segment parameter models were used to obtain centre of mass data as these have been found to be most suitable for analysis of elite race walking[7]. Data for the left and right sides of the body have been averaged wherever appropriate (i.e. for knee angles). Details of each athlete analysed are included in Table 1. Pearson's product moment correlation coefficient was used to find associations using all 15 athletes as a single group of world-class athletes.

Results and Discussion

The key race walking performance parameters for each analysed athlete are shown for each event in Table 2. The velocities recorded were those measured at the particular distance of analysis and might differ slightly from the average velocity for the entire race. Indeed, all five gold medallists recorded negative splits in that their second half of the race (when they were analysed) was faster than the first. It can be seen that the six fastest walkers competed in either the senior men's 20km or the junior men's 10km races.

Race walking velocity is the product of stride length and stride frequency[4], both of which are shown in Table 2. As shown in Figure 1, velocity was correlated with stride length (r = 0.85, p < .001) when taking all 15 analysed athletes into account, although velocity was not found to correlate with stride frequency (r = –0.31, p = .256).

Table 1: Participants, ages (yrs), performances and other notable successes

Place	Athlete	Age	Time	Additional comments
20km Senior Women				
1	Elena Lashmanova (RUS)	20	1:27:38	2012 Olympic Champion
2	Olga Kaniskina (RUS)	27	1:28:33	2008 Olympic Champion
3	María José Poves (ESP)	34	1:29:10	
20km Senior Men				
1	Zhen Wang (CHN)	20	1:19:13	2012 Olympic bronze medallist
2	Andrey Krivov (RUS)	26	1:19:27	
3	Vladimir Kanaykin (RUS)	27	1:19:43	2011 World Champs silver medallist
50km Senior Men				
1	Sergey Kirdyapkin (RUS)	31	3:38:08	2012 Olympic Champion
2	Igor Erokhin (RUS)	25	3:38:10	
3	Jared Tallent (AUS)	27	3:40:32	2008 / 2012 Olympic silver medallist
10km Junior Women				
1	Sandra Arenas (COL)	18	45:57	2012 World Junior bronze medallist
2	Alejandra Ortega (MEX)	17	46:00	
3	Nadezhda Leontyeva (RUS)	18	46:02	2012 World Junior silver medallist
10km Junior Men				
1	Eider Arévalo (COL)	19	41:17	2012 World Junior Champion
2	Alexander Ivanov (RUS)	17	41:42	
3	Jesús Tadeo Vega (MEX)	17	41:56	

Table 2: Key race walking performance parameters

Athlete	Velocity (km/hr)	Stride length (m)	Stride length difference (m)	Stride frequency (Hz)
20km Senior Women				
Lashmanova	14.53	1.21	0.02	3.34
Kaniskina	13.20	1.08	0.02	3.39
Poves	13.38	1.06	0.05	3.49
20km Senior Men				
Wang	15.31	1.27	0.02	3.35
Krivov	14.79	1.35	0.02	3.03
Kanaykin	15.49	1.31	0.05	3.30
50km Senior Men				
Kirdyapkin	14.10	1.16	0.02	3.39
Erokhin	13.92	1.16	0.00	3.32
Tallent	13.66	1.11	0.04	3.42
10km Junior Women				
Arenas	14.27	1.16	0.05	3.41
Ortega	14.11	1.17	0.00	3.36
Leontyeva	14.00	1.12	0.00	3.48
10km Junior Men				
Arévalo	15.78	1.23	0.01	3.55
Ivanov	15.28	1.36	0.01	3.13
Vega	14.92	1.30	0.04	3.20

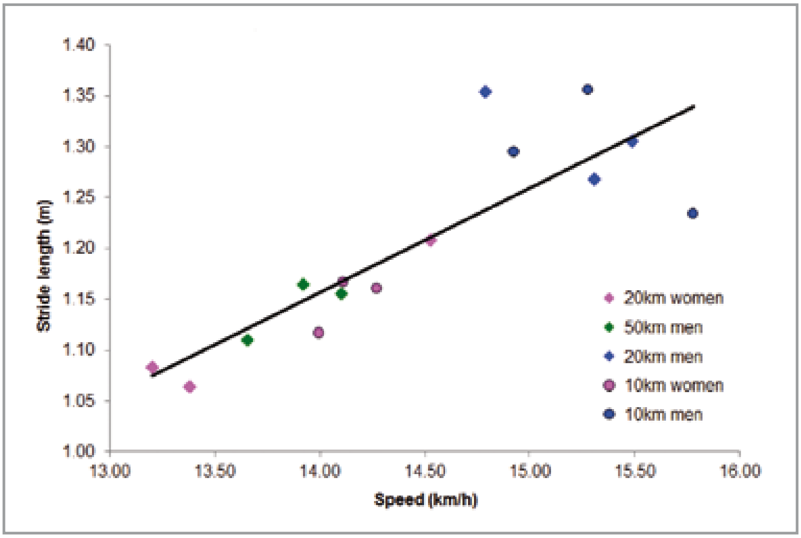

Figure 1: The relationship between velocity and stride length for all 15 participants

Stride length and stride frequency were found to be negatively correlated with one another, in that athletes with longer strides were found to have lower stride frequencies (r = –0.76, p = .001). Stride length differences varied throughout the group, with some athletes having equally long strides while others had up to 5cm difference. These differences might be indicative of imbalances between left and right sides of the body and could be measured (e.g. by coaches) at various distances during training to establish how frequently such differences occur, what effect they might have, and if changes occur with fatigue.

Elena Lashmanova won the women's 20km event in a time of 1:27:38, more than two and a half minutes slower than the world record time she set 3 months later when winning at the Olympic Games in London. This slower time (and those of other athletes) was partly due to the difficult weather conditions in Saransk (e.g. a temperature of 30°C was recorded at both the beginning and end of the women's 20km race). The runner-up to Lashmanova in both Saransk and London was the 2008 Olympic and three-time World Champion Olga Kaniskina. Lashmanova was by far the fastest of the three medallists at the instance of analysis: her higher race walking velocity was due to a much longer stride length (13cm longer than Kaniskina's and 15cm longer than that of bronze medallist, María José Poves). By contrast, Lashmanova had the lowest stride frequency and highlighted the significance of stride length in elite performances as shown by the correlations above.

The importance of stride length in fast race walking was also shown in the results found for the 20km men, as the two fastest men at this point (Zhen Wang and Vladimir Kanaykin) had relatively long strides. However, the negative relationship between stride length and stride frequency was underlined by the data found for Andrey Krivov who had the longest stride of this trio (and the second-longest of the 15 athletes) but by far the lowest stride frequency of all analysed athletes. Interestingly, the longest strides measured in the whole sample (1.36m) were obtained for Alexander Ivanov in the junior men's race, who had the second-lowest stride frequency. The average stride frequency of all 15 athletes was 3.34 Hz (which equates to 200 strides per minute) and this is a useful guide for coaches who wish to develop their athletes to world-level.

In the men's 50km race, walking velocity is of course lower compared with the shorter 20km race as the athletes attempt to balance a competitive pace with the need to delay and withstand fatigue. It was informative that the 3 medallists' lower walking velocitys (approximately 1.3 km/hr slower than the 20km medallists) were achieved with shorter strides rather than lower stride frequencies and this again suggests that there could be an optimal range of stride frequencies in elite race walking. The 50km gold medallist, Sergey Kirdyapkin, became Olympic Champion in London three months after the World Cup, having twice won over the same distance at the IAAF World Championships in Athletics (2005 and 2009). His technique can be therefore seen as an excellent model in terms of balancing stride length and stride frequency.

In addition to Kirdyapkin, the other eight senior medallists at the World Cup went on to compete at the Olympic Games in London. The two junior gold medallists (Eider Arévalo and Sandra Arenas) also completed in the Olympic 20km events, finishing 20th and 32nd respectively.

It is worth noting that 2012 was Lashmanova's first year out of junior competition. The transition to senior competition can be difficult even for elite junior race walkers because of the doubling of distance, but an efficient race walking technique with a sound biomechanical basis can make this transition easier. In Saransk, the analysed walking velocitys of the medallists in both junior races were similar to those of their senior 20km counterparts, and it can be seen that in general their stride lengths and stride frequencies matched closely those of the older athletes. It can of course take much longer for junior athletes to become successful senior athletes but an important component to emphasise during all young athletes' development is correct race walking technique.

Stride frequency is dependent on the duration of both contact time and flight time. The values for both these variables are shown in Table 3 along with the percentage of time per stride spent in contact with the ground. Very brief flight times are not visible to the human eye and explain why there were few red cards written for loss of contact (IAAF rule 230.1) for the 15 athletes. However, there were more red cards amongst the faster athletes (e.g. 20km senior men) as the walkers got closer to the threshold of visibly losing contact. Short contact times have been previously shown to be hugely important in faster race walking[4] and the results found for these 15 elite athletes indicate near-optimal values.

Table 4 shows the averages of the hip and knee joint angles at both contact and toe-off. The small standard deviations reported for each group indicate that variation between athletes was small for both joints at first contact, although there were slightly larger variations at toe-off. The small ranges found during this part of the gait cycle are undoubtedly a consequence of the rule that requires a straightened knee at first contact with the ground until the 'vertical upright position' (IAAF rule 230.1). These elite race walkers adhered to the rule very well; on average, the athletes were found to have fully extended their knees at first contact, and indeed further hyperextension of the knee occurred until the vertical upright position (midstance) where the average knee angle was 192° (± 4).

In contrast with the lower limb angles, there were much larger variations in the upper limb joint angles measured in this sample of athletes (Table 5). The shoulder angles at contact indicate the amount of shoulder hyperextension occurring on the same side as the heel striking the ground (and are typical of the high elbow drive associated with race walking technique) while the shoulder angles at toe-off indicate

Table 3: Temporal data (mean ± SD) and total red cards (loss of contact)

	Contact time (sec)	Flight time (sec)	Contact time (%)	Red cards (~)
20km Senior Women	0.26 (± .00)	0.03 (± .01)	88.7 (± 3.6)	0
20km Senior Men	0.26 (± .02)	0.05 (± .01)	84.7 (± 4.1)	2
50km Senior Men	0.26 (± .00)	0.04 (± .00)	86.7 (± 0.0)	0
10km Junior Women	0.25 (± .01)	0.04 (± .00)	86.3 (± 0.5)	3
10km Junior Men	0.26 (± .02)	0.04 (± .00)	86.6 (± 0.9)	1

Table 4: Lower limb joint angles for each group of athletes (mean ± SD)

	Hip joint		Knee joint	
	Contact (°)	Toe-off (°)	Contact (°)	Toe-off (°)
20km Senior Women	165 (± 2)	196 (± 2)	184 (± 1)	161 (± 1)
20km Senior Men	170 (± 2)	190 (± 2)	186 (± 2)	153 (± 6)
50km Senior Men	170 (± 1)	191 (± 3)	184 (± 2)	164 (± 4)
10km Junior Women	171 (± 1)	196 (± 4)	183 (± 2)	164 (± 8)
10km Junior Men	170 (± 3)	190 (± 3)	181 (± 4)	159 (± 4)

Table 5: Upper limb joint angles for each group of athletes (mean ± SD)

	Shoulder joint		Elbow joint	
	Contact (°)	Toe-off (°)	Contact (°)	Toe-off (°)
20km Senior Women	70 (± 11)	44 (± 13)	80 (± 28)	68 (± 26)
20km Senior Men	65 (± 14)	39 (± 7)	84 (± 12)	75 (± 17)
50km Senior Men	55 (± 8)	40 (± 8)	81 (± 7)	65 (± 9)
10km Junior Women	58 (± 7)	42 (± 11)	82 (± 10)	75 (± 7)
10km Junior Men	65 (± 7)	39 (± 7)	77 (± 14)	65 (± 13)

flexion (the arm is in front of the body). Adding the two values together gives the total range of motion of the shoulder, and it can therefore be seen that the shoulder's overall range during a single stride was approximately 100°. Slightly higher ranges were found for the women's 20km athletes (114°) whereas the lowest values were found in the 50km medallists (95°).

Most race walkers hold their elbows in whatever position feels comfortable but the best angle might not be adopted naturally. While the overall average elbow angle at contact was 81°, there were very large variations found in all groups, and in particular amongst the 20km women. This was due to one medallist (Lashmanova) having the largest elbow angle of all 15 athletes (109°) and another (Poves) having the smallest (53°). The comparable large variations for the elbow joint at toe-off were also caused by such large discrepancies between athletes. The fact that world-class race walkers can differ so greatly in appearance shows that there is little effect of the race walking rule on the arm's movements (as there is on the legs) and that there is not just one successful technique. Race walkers generally hold and move their arms in balancing the movement of the legs but coaches should consistently observe their athletes in order to ascertain if arm swing is helping or hindering the legs' rhythm.

Conclusion

Selecting the very best athletes for analysis is useful when the aim is to identify the most important variables in successful race walking. The majority of the 15 medallists analysed in this study were closely matched in terms of stride frequency and so the greater importance of stride length to race walking velocity was evident. However, athletes should note that there is a limit on how much stride length can be increased before stride frequency is reduced to detrimental levels. Furthermore, increases in stride length might be achieved through longer flight times, which can lead to disqualification. The athletes analysed in this study were some of the world's best and had the ability and prior training to achieve long strides at high frequencies while maintaining legal race walking technique. Coaches and athletes should note that every race walker's technique is different (as emphasised by the variations in upper limb joint angles) and each individual's strengths and weaknesses need to be identified to achieve their own optimal race walking technique.

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