Analysis of Gait efficiency and foot placement for Egyptian race walker

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Introduction

Race walking is a progression of steps so taken that the walker makes contact with the ground, so that no visible (to the human eye) loss of contact occurs. the advancing leg must be straightened (i.e. Not bent at the knee) from the moment of first contact with the ground until the vertical upright position.(IAAF , 230 ,2014)

This rule was introduced in 1995, and before 1995 the leg had to be straightened only in the vertical position. Those restriction (no flight time and straightened knee) forced athletes to develop a characteristic locomotors pattern widely known as "race walking style". Despite being a worldwide discipline. Moreover some of them were published before 1995, hence they could not be fully relevant to the current race walking analysis, being based on the old rules. (Gaspare Pavei, et el .2014)

To develop performance of Egyptian race walker while perfecting their technique so they remain within the rules and avoid disqualification there are more parameters need to be adjusted "stride length, foot angle, step length, step rate, stride time, step time need to special derails and training.

Therefore a stride in race walking is a sequence of event taking place between successive hell contacts of the same foot. A Gait cycle has two step –a left step and right step. The basic spatial description of gait cycle include the length of a stride , the length of step, step width ,foot angle .Stride length is the distance between two successive heel contacts of the same foo. step length on the contrarily is the distance between successive heel contacts of the two different feet. The basic temporal descriptor of gait cycle is stride frequency (step rate) other temporal descriptor of gait cycle are stride time (time for the full gait cycle), step time (the time for the completion of a right or a left step) and walking speed (combines both spatial and temporal measurement). A full gait cycle for the right lower extremity can be divided into two major phases: stance phase include 60 % of gait cycle (from right heel contact to right toe off) and swing phase include 40 % of gait cycle (from right toe off to the next right heel contact).In the normal walking the center of mass total vertical displacement 5 cm and total side to side displacement 4 cm during gait .(Donald A. Neumann,2010, pp631-637)

The stride length (SL, m) and the stride frequency (SF, Hz) are the positively correlated determinants of walking speed, but they seem not to correlate with each other (Hanley et al., 2011a, 2011b; Padulo et al., 2013a; Padulo et al., 2013b; Preatoni, La Torre, Santambrogio, & Rodano, 2010a) By pooling together data from (Gaspare Pavei et al 2013) study a computed descriptive equation which estimates stride length value (m) at a given speed (v, m.s-1). was established. stride length better correlated than SF to speed as shown by Hanley et al. (2011a) in their narrow range of speed. The steeper stride length slope compared with stride frequency at increasing speed was related to an increase in flight time and, consequently, a decrease in contact time (Padulo et al., 2013a).

During race walking the speed reduced due to the drop in stride length, and successively to a stride frequency decrease. In the 50 km both speed and stride length decreased with a significant reduction of flight time, whereas stride frequency was steady over the race; moreover ankle plantarflexion at toe off and the pelvis rotation were decreased (Hanley et al. 2011b)

Recently Padulo et al. (2013a) measuring stride length and stride frequency at the same speed at level and on gradient (2% and 7%): stride length decreased, probably due to a reduction of swing phase because of the incline, contact time decreased, whereas SF increased. Later Padulo et al. (2013b) found also a decrease in SF with an increase in contact time that was addressed to a decrease in speed from level to 7% in order to maintain the “iso-efficiency speed”, which is the speed value that leads to a constant energy cost across the slopes.

The knee 'restriction' when the lower limb was straightened at heel strike (Hanley et al., 2011a, 2011b; Neumann et al., 2006, 2008; Zhang & Cai, 2000) and when the knee hyperextended for almost the 70% of the contact time, with a peak at midstance of about 10° (Donà, Preatoni, Cobelli, Rodano, & Harrison, 2009).

Hanley and Bissas (2013) proved that ankle torque is not the only power generator, but hip extensors and ankle plantar flexors moments are also fundamental to accelerate the body center of mass through an energy transfer from the hip to the ankle via the straightened knee. The absorbing power obtained during the knee flexion before toe off is crucial to provide more time to the swinging leg in order to land ahead and avoid flight phase. Moreover Hanley & Bissas (2013b) focused their investigation on the functional role of the swinging leg: peak joint moment and power of knee and hip correlated with speed occurred during swing and could be a defining feature of better performances. (Hoga et. al. 2003,2006)

At heel strike the ankle is dorsiflexed compared with the standing position, the knee is fully extended and the hip is flexed relative to the standing position; the contralateral shoulder is extended and the elbow is reported to have an angle of 79°±9° (Hanley et al., 2011a). At midstance the ankle is still dorsiflexed, the knee is hyperextended of about 10°, the shoulder is flexed and the elbow has almost a flexion of 82°±7° (Hanley et al., 2011a). At toe off the ankle is plantar flexed, the knee is flexed, the hip is extended, the contralateral shoulder is flexed and the elbow is flexed 67°±7° (Hanley et al., 2011a).

The flight time has been detected in several studies and its duration (0.01 – 0.05 s) varied with speed (Hanley, Bissas, & Drake, 2011a, 2011b; Neumann, Krug & Gohlitz 2006, 2008). In race condition, Hanley et al. (2011a, 2011b), found a flight time of 0.03s for a male 20 km race (speed = 4 m.s-1, 14.5 km.h-1) and 0.02 s for a female 20 km and male 50 km race (3.5 – 3.6 m.s-1, 12.7 km.h-1 – 13.1 km.h-1 respectively).
The aim of this study is to measure and evaluate the role of some parameters which is related to performance for Egyptian race walkers and coaches. It will help them to realizes the beneficial of this parameters to a more efficient race walking. This can lead the race walkers to improve their walk and retain more of their energy.

METHODS: Data Collection: Subjects. 7 male competitive walkers volunteered as subjects for this study (22 ± 3 yrs, 1.75 ± .05 m, 68.3 ± 5.8 kg) and 5 (21 ± 4 yrs, 1.67 ± .05 m, 63.2 ± 3.9 kg) women, All 12 men had previously competed over 20 km (time :92.38 ± 1:71) 1 /10/2014 Cairo stadium , The investigating period was in the competition. Data Analysis: Use Dartfish v4.5 program to calculate data Race walking speed was determined as the mean horizontal speed of the center of mass during one complete gait cycle (using Dartfish) Video data were collected at 100 Hz using a high-speed camera. 1 camera was placed approximately 12 m from and perpendicular to the line of walking and 2ed camera was placed approximately 5 m from and perpendicular to the finish line. Step length was measured as the distance between successive foot contacts using the Dartfish. stride frequency was calculated by dividing horizontal speed by step length. The distance the whole body center of mass travelled during flight was measured from the instant of toe-off of one foot to the instant of initial contact of the other and termed flight distance. With regard to angular, the knee angle was calculated as the sagittal plane angle between the thigh and leg segments and was considered to be 180° in the anatomical standing position. The hip angle was defined as the sagittal plane angle between the trunk and thigh segments and was also considered to be 180° in the anatomical standing position. The ankle angle was calculated in a clockwise direction using the lower leg and foot segments and considered to be 110° in the anatomical standing position, probability level of 0.05 was accepted as significant.

Table 1. Value, mean and SD of parameters effect on race walker performance .

Measurement	**Mean (SD)**	
	Male (n=7)	**Female (n=5)**
stride length (m)	2.56 (± 0.06)	2.32(± 0.07)
stride time (s)	0.631 (± 0.01)	0.668 (± 0.03)
Step length (m)	1.13 (± 0.03)	1.03 (± 0.07)
Flight time (s)	0.02 (± 0.01)	0.03 (± 0.01)
stride frequency (Hz)	3.16 (± 0.06)	3.21(± 0.05)
foot angle (°)	17 (± 3.2)	22 (± 4.1)
Knee at contact (°)	177 (± 2.3)	178 (± 2.3)
Hip angle (°)	171 (± 1.69)	173 (± 1.69)
Pelvic rotation (°)	14 (± 2)	9.8 (± 1.64)
Shoulder rotation (°)	19 (± 2)	22 (± 3)
Leg pathway Deviation (	15.45 (± 1.69)	17 (±1.92)
Speed (km/h)	12.89 (± 0.13)	8.70 (± 0.36)
Performance time (min)	92.38 (± 1.71)	150.40 (± 17.64)

Values are means _ SD. Stride length, stride time, step length, flight time, stride frequency, foot angle, Knee at contact, Hip angle, Pelvic rotation, Shoulder rotation, Leg pathway Deviation, Speed and Performance time

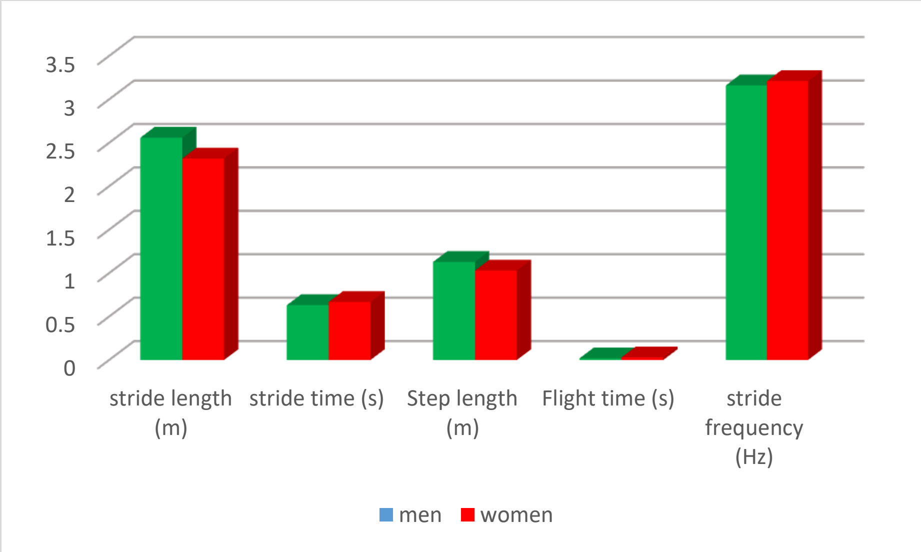

Figure 1. Stride length, stride time, step length, flight time, stride frequency.

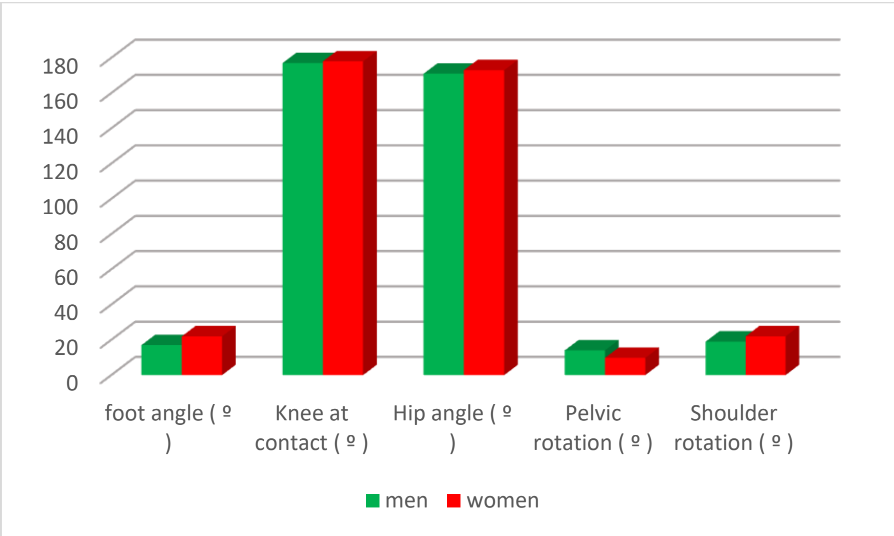

Figure 2. foot angle ,Knee at contact ,Hip angle, Pelvic rotation, Shoulder rotation.

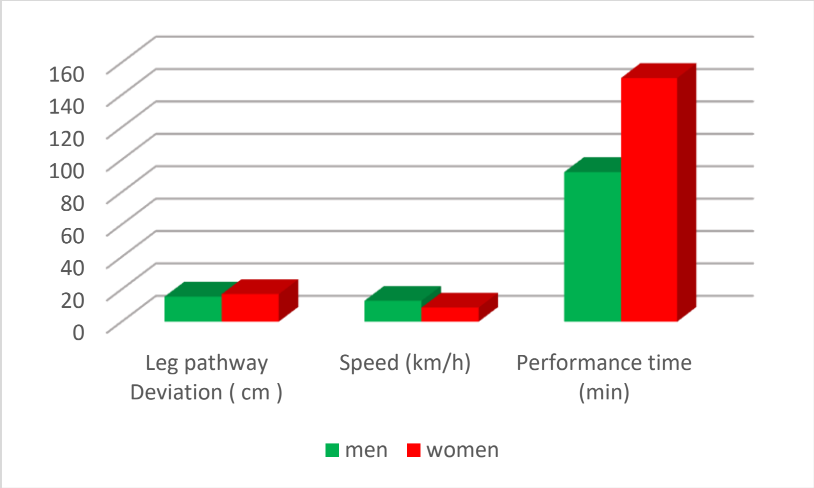

Figure 3.Leg pathway Deviation, Speed, Performance time

Table 2. The deference between men and female in parameters

Measurement		N	Mean Rank	Sum of Ranks	Z	*P*
stride length (m)	M	7	5.81	46.50	1.404	.160
	F	5	8.90	44.50		
stride time (s)	M	7	5.19	41.50	2.128	.033
	F	5	9.90	49.50		
Step length (m)	M	7	8.69	69.50	1.984	.047
	F	5	4.30	21.50		
Flight time (s)	M	7	4.75	38.00	2.707	.007
	F	5	10.60	53.00		
stride frequency (Hz)	M	7	7.38	59.00	-.444	.657
	F	5	6.40	32.00		
foot angle (°)	M	7	5.69	45.50	1.552	.121
	F	5	9.10	45.50		
Knee at contact (°)	M	7	6.00	48.00	1.213	.225
	F	5	8.60	43.00		
Hip angle (°)	M	7	5.25	42.00	2.096	.036
	F	5	9.80	49.00		
Pelvic rotation (°)	M	7	4.88	39.00	.304	.761
	F	5	10.40	52.00		
Shoulder rotation (°)	M	7	6.94	55.50	.075	.941
	F	5	7.10	35.50		
Leg pathway Deviation (cm)	M	7	6.75	54.00	.304	.761
	F	5	7.40	37.00		
Speed (km/h)	M	7	9.50	76.00	2.944	.003
	F	5	3.00	15.00		
Performance time (min)	M	7	4.50	36.00	2.932	.003
	F	5	11.00	55.00		

The results indicated that is significant statistical difference between male and female race parameters measurements (stride time, Flight time, Hip angle, Speed, Pelvic rotation, Performance time).

Table 3. Correlation coefficients (r^2) between Parameters and Performance time

	Measurement	Male	Female
1	stride length (m)	-0.89*	0.896*
2	stride time (s)	0.88*	0.887*
3	Step length (m)	0.754*	-0.396
4	Flight time (s)	0.833*	0.093
5	stride frequency (Hz)	0.734*	0.899*
6	foot angle (º)	-0.757*	-0.513
7	Knee at contact (º)	0.817*	0.775
8	Hip angle (º)	-0.77*	0.799
9	Pelvic rotation (º)	-0.663	-0.765
10	Shoulder rotation (º)	0.650	-0.615
11	Leg pathway Deviation (	-0.890*	-0.092
12	average Speed (km/h)	0.837*	0.793

Performance time was correlated with stride length(r = 0.727), stride time (r = 0.756), Step length(r = 0.740), flight time (r = 0.810), stride frequency (r= 0.734), Knee at contact (r = 0.817), average Speed (r = 0.837) and was negatively correlated with foot angle (r = –.757) and Leg pathway Deviation for men but stride length (r =0.896), stride time (r = 0.887), stride frequency (r =0.899) for women.

DISCUSSION:

The results in table (1) and figures (1,2,3) indicated that Flight times occurred in all 12 participants, was longer flight times associated with higher walking speeds and longer steps. More importantly, the resulting longer flight distances were therefore also a reason for overall greater step lengths. It is thus very clear that the brief flight phases that Egyptian race walkers undertake are an important factor in their performances. Step lengths would have an average of 10 cm shorter coming from foot placement, while the concurrent reduction in step time would have resulted in mean stride frequency of 3.16 Hz for male and 3.21Hz for female that are far higher than those reported of world-class race walkers in competition.This comply with what has been mentioned by (Hanley, Bissas & Drake, 2011).However, such an eventuality would lead to decreases in walking speed of only 0.10 km/h. by this the Egyptian walker had a considerable negative consequences in competition.

In the transverse plane the pelvic rotation was nearly to normal results 14°±2°for male ,15.8°±1.64° for female. According to(Hanley et al.2011a) Estimated pelvic angle using hip joint coordinates was an angle of 18°±3°. It can be addressed to a varying reference selection for joint angle measurement. (Hanley et al. 2011a) in differently with (Hanley and Bissas 2013) showed hip, knee and ankle joint angular time course during a stride, which may be an important functional parameter for a more complete picture of the locomotion pattern and to provide coaches and athletes with a further technical feedback suitable in training. Race speed can be increased mainly by developing a longer stride length, which can be generated by a higher propulsive time phase, hence training methodology should be a specific Practical applications which will provide coaches by reliable race walking technique analysis on performance. Ankle and hip as the main determinant of propulsive torque and speed, and leg swing seems to play a role on speed generation. Coaches must be encouraged to a quantitative focus on training specifically stride length and stride frequency. also in relation to fatigue, rather than relying only on the qualitative typical check drills. in male athletes stride length and stride frequency could be both optimized for improving their performance (Pavei et al 2014)

The differences between male and female may be due to the female using different angels to improve pushing and stride length amount of produced movement from ankle joint to increase feet pushing, this difference in performance came from the male experience and training quantity. Female race 20 km was applied recently in Egypt so female try to compensate speed in stride length and frequency this comply with what has been mentioned by (Witt et. al. 2008) (Pavei et al 2014)

The results in table (1,3)The relationship of Performance time with stride length(r = 0.727), stride time (r = 0.756), Step length(r = 0.740), flight time (r = 0.810), stride frequency (r= 0.734), Knee at contact (r = 0.817), average Speed (r = 0.837). And it was negatively in correlation with foot angle (r = –.757) and Leg pathway Deviation for men. In trying to compensate the Leg pathway Deviation in some male walker they had to reduce the stride length 2 cm per 15 degree deviation in pathway for leg in swing phase while some walker increase the Pelvic rotation and hip to optimize their stride length to maintain the speed race, for female Stride length (r =0.896), stride time (r = 0.887), stride frequency (r =0.899) stride length and frequency could be both optimised for improving their performance by specific training to increase stride length that could gain even major benefits to female performance. Egyptians walker comply with the straightened knee rule, and have no visible loss of contact. Lifting tends to occur for 0.02 seconds for male and 0.03 seconds for female or less even in the very fastest walkers. Egyptians race walkers have step lengths approximately 64.57 % of their height for male and 61.67% for female. Egyptians race walkers have less pelvic rotation and more upper body movement.

Recommendation :

- All Egyptian walker must increase the stride frequency to maintain technique and avoid disqualification by using special derails.
- Improve pushing and stride length amount of produced movement from ankle joint to increase feet pushing in preparing period.
- Race speed must be increased by developing a longer stride length, which can be generated by a higher propulsive time phase.

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