Analysis Of Junior Race Walking Technique In Relation To Walking Velocity

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ABSTRACT

Pedestrians capable of traveling in excess of 10 miles per hour, they zip along with rhythmic synchronicity (Salvage J. & Seaman T. 2011). The present study aimed to investigate the association and relation of kinematic, physiologic and kinanthropometric properties with the walking velocity. To meet these purpose top 10 race walkers of 10000m race walk event (Men-20) were analyzed, from 33rd National Junior Athletics Championships, 2017 held in Vijayawada. Athletes were recorded as they passed through 4.55 KM on the 400 m track by using two standard digital HD camcorders (Nikon B700, 60Hz). The video data were analyzed by using motion analysis software (KINOVEA 0.8.27).Whereas, kinanthropometric measurements were taken by using the standard Issac procedure. To measure Vo_2 max athlete's performance were taken as they passed through 1.5 miles or 2414.02 m on the track. The result of the study showed that the correlation between race performance and VO_2 max was quite high, r (8df) = 0.726. Quite high and significant positive association were found in stature, shoulder width, lower limb length and foot length with velocity (r = 0.650,0.683,0.741 and 0.670 respectively). A Strong relationship was found between step length and RW performance, i.e. r (8df) = 0.689. Whereas variables like, flight time, linearity, maximum knee and foot height of swing leg were positively correlated with the walking performance. A high degree positive association was located in the torso and pelvic displacement r = 0.768 & 0.804 respectively. In toe off phase "r" value of knee angle with performance was 0.742 that showed a high degree coefficient of correlation. Whereas at heel contact and mid stance phase a low degree negative correlation found (r = -0.489 & -0.406). High degree positive relationship found in ankle angle in heel contact other than rest two phases i.e. r = 0.637. Most of the calculated "r" values were significant as the critical value of 8 df at 0.05 level is 0.631. Due to the direct association of race walking velocity (Mean = 3.427 m/s & SD = 0.235) with VO_2 max, step length, knee angle, torso & pelvic displacement may be this type of result found in different phases. But, the relationships of some kinematic variable with the race walking performance were very much closer to be significantly significant.

Keywords: Pedestrian, heel contact, mid stance, toe off, kinematic, VO_2 max, etc.

Background

IAAF competition rules (2018-2019) 230.2. define 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.

The 18th and 19th century English tradition of "footmen", who accompanied their masters' coaches on long trips, inspired long distance walking competitions, called pedestrian races, which were first held between 1775 and 1800 in

England. Often, these took several days to complete. However, not all pedestrian races were so long. For example, Charles Westhall, a well-known pedestrian who in 1852 also became the first runner to break 4:30 for the mile on a track, was reported to have walked seven miles in 54 minutes at New market Heath (MARLOW, 1990). A particularly famous pedestrian was Robert Barclay Allardice, a Scots nobleman born in 1779, who was widely known as Captain Barclay. As was common at the time, the many walking and running feats he undertook were nearly always on a bet. In 1809, he contracted to cover 1,000 miles by walking one mile per hour in 1,000 consecutive hours for a wager of 1,000 guineas. The event started on 1 June and ended on 12 July and attracted extensive press coverage. It is estimated that in completing the challenge Barclay received many times the original wager inside bets and that all the bets placed on the event totaled 100,000 pounds, the equivalent of 40 million pounds in today's money (RADFORD, 2002). In modern times, race walking is an Olympic discipline with distances of 20km for both men and women and 50km for men only. Race-walking events also appear in the IAAF World Championships in Athletics, the Commonwealth Games and the Pan American Games, among others. Race walking first appeared in The Olympic Games in 1904 as a half-mile walk in the 'all-rounder,' the precursor to the 10-event decathlon. In 1906, stand-alone 1,500m and 3,000m race-walking competitions (for men) were added, and – excluding 1928 – there has been at least one race-walking competition in every Olympics since.

The technique of RW is not a naturally obtained human skill as normal walking and running are obtained in childhood (Payne & Payne, 1981). Pedestrians walk with top speed and technique in competition is one of the most important factors to achieve higher performance in National and International level race walking event in track & field. The technique of race walking which is defined by IAAF race walking rules 230.2 is not a naturally obtained human skill as normal walking and running are obtained in childhood (Payne & Payne, 1981). Race walking event requires utmost beauties on the skill part, i.e. heel contact, mid stance and toe off of the advancing leg. Elite race walkers moved with a fluidity and grace that are the envy of anyone who has tried the low impact yet high intensity sport of race walking. Most economical race walkers may have distinct race walking patterns (Hanley & Bissas, 2017). They capable of traveling in excess of 10 miles per hour, they zip along with rhythmic synchronicity (Salvage J. & Seaman T. 2011). Race walking is part of the athletics program at the Olympic Games and all other major athletics championships. Races for junior men and women (under 20 years of age) are held over 10000m. 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. 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. While it is very useful to measure biomechanical and physiological variables across large groups of athletes, it is equally valuable to focus on performances of the very best athletes in understanding the determinants of fast race walking. In race walking, the single most important factor in competitive success is speed, although this is restricted by the two unique rules of race walking technique. At the most basic level, speed is determined by step, or stride, length and stride frequency. The position of the support foot in relation to the athlete's whole body center of mass is important in maintaining forward speed. A foot landing too far in front of the body at initial contact can cause too great a braking impulse (LAFORTUNE et al., 1989). The distance to the support foot at toe-off is important in generating adequate stride length and forward propulsion (HOGA et al., 2003).

Unlike other endurance sports, race walking is governed by strict biomechanical rules, as athletes are not allowed to have any visible loss of contact with the ground and must maintain a straightened knee from the initial contact with the ground until the vertical upright position (IAAF, 2019). The result of this is a distinct gait pattern and the need of not only endurance capacity, but also a great technical ability to perform at elite level (Hanley, Bissas, & Drake, 2013). For example, non-peer reviewed evidence suggests that when race walking, the optimum foot position at initial contact is directly under the center of mass, as a foot ahead approaching zero would result in considerably reduced braking forces and, therefore, help maintain forward momentum (Summers, 1991). This would lead to a subsequent reduction in step length, which contrasts with research suggesting that larger step lengths would contribute to faster race walking speeds in elite race walkers (Hoga, Ae, Enomoto, & Fujii, 2003). Other researchers have reported smaller vertical oscillations and longer flight times as key factors for increased walking speeds (Hanley & Bissas, 2017).

Success in race walking is related more to the efficiency of technique rather than physiological factors (HOGA et al. 2003). The correction and optimization of technique is therefore of great importance. Modifications in gait patterns may affect the energy cost of walking (BRISSWALTER et al., 1998) and these modifications can be caused by fatigue. When the body is placed under immense physical pressure in endurance events such as race walking, performance can deteriorate due to the effects of fatigue. Athletes can normally continue performing whilst experiencing fatigue, but their technique may alter (BRISSWALTER et al., 1998). Various studies have reported that athlete's height, limb length etc. have great importance in walking performance. This is especially important in race walking, as poor technique can lead to disqualification. In order for athletes to improve their overall performance, knowledge of when their technique starts to change and ways to combat changes may help prevent technique deterioration. A theoretical framework of which variables are most important to race walking success can then be considered and used by athletes and coaches to highlight indicators of success and relevant strengths and weaknesses.

Objectives

The aim of this study was to analyze and investigate the association and relation of kinematic and physiologic properties with the race walking performance.

There were three objectives towards achieving this aim.

- First, to find associations of performance within the important kinematic (linear and angular) variables that can suggest methods of improving performance.
- Second, to find out the degree of association between kinanthropometric measures and walking velocity.
- Third, to measure the aerobic capacity (VO_2max) as a physiological parameter to locate the association and significance with race walking (RW) performance.

Methodology

Subjects

Top ten competitors of U-20 Men, 10000m race walk event in 33rd National Junior Athletics Championships, Nov, 2017 held at Acharya Nagarjuna University, Vijaywada, A.P. were analyzed as a subject of the study.

Criterion measures

Table 1: Details of selected kinematic and physiologic variables

Criterion	Measure
KINEMATIC PARAMETER	
Linear Kinematics	
Velocity	m/s
Stride length	Centimeter
Flight distance	Meter Centimeter
Flight time	Sec.
C of G height from the ground	Centimeter
Torso displacement	Centimeter
Pelvic displacement	Centimeter
Maximum foot height of swing leg	Centimeter
Maximum knee height of swing leg	Centimeter
Angular kinematics	
Leanirty	Degree
Knee angle	Degree
Ankle angle	Degree
Right elbow angle	Degree
Left elbow angle	Degree
PHYSIOLOGICAL PARAMETER	
VO_2 Max (Larsen GE, VO_2 Max Prediction Equation, 2002)	Ml/kg/min
KINANTHROPOMETRIC PARAMETER	
Stature	Centimeter
Shoulder width	Centimeter
Upper limb length	Centimeter
Lower limb length	Centimeter
Foot length	Centimeter

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.

• Mid-stance: The point where the athlete's foot was directly below the body's center of mass, used to determine the 'vertical upright position' (IAAF Rule 230.1).

• Toe-off: The last visible point during stance where the athlete's foot clearly contacts the ground.

Procedure of collection of data

For kinematic analysis, athletes were recorded as they passed through 4.55 KM at the back straight on the 400m track by using two standard digital HD camcorders (Nikon B700, 60Hz) mounted on rigid tripods 4 m away from the track inside & outside where reference volume was 5 m long and 1.5 m high. The video data were analyzed by using motion analysis software (KINOVEA). To determine Vo_2 max, athletes' performances were taken as they passed through 1.5 miles or 2414.02 m on the track and then that elapsed timing of the particular athlete has been plotted in Larsen GE, VO_2 Max Prediction Equation (2002), formula.Whereas kinanthropometric measurements were taken by using the standard Issac procedure. To measure weight, digital weighing machine applied.

Statistical technique

Descriptive statistics & Pearson's product moment correlation coefficient were employed to find the associations of RW performance with the kinematic and physiologic variables. The significance level was set at 95% of confidence (***p*<0.05**). The tabulation of data was done by using the IBM SPSS software.

Findings and Discussions

Table 2: Descriptive analysis of kinematic physiologic & kinanthropometric variables of junior (top 10) race walkers

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation($\pm$)
Ave. Velocity (m/s)	10	3.00	3.88	3.43	0.33
VO_2 max (ml.kg^{-1}.min^{-1}.)	10	54.96	56.39	55.62	0.59
Stride length (cm)	10	88.39	100.49	92.42	3.79
Flight distance (cm)	10	11.87	29.95	22.04	6.90
Flight time (sec)	10	.05	.09	0.07	0.01
Torso displacement (cm)	10	18.62	23.92	21.09	1.78
Pelvic displacement (cm)	10	.46	3.88	1.83	1.26
Max. Foot height of swing leg (cm)	10	39.00	46.92	41.49	2.31
Max. Knee height of swing leg (cm)	10	60.74	70.02	63.49	2.71
Leanerity (^{0})	10	.00	11.00	6.40	3.53
Knee angel at Heel contact (^{0})	10	178.00	186.00	180.70	2.45
Ankle angel at Heel contact (^{0})	10	100.00	106.00	103.40	2.12
Knee angel at Mid Stance (^{0})	10	178.00	198.00	185.60	5.52
Ankle angel at Mid Stance (^{0})	10	103.00	118.00	108.40	4.72
Knee angel at Toe off (^{0})	10	145.00	154.00	150.10	2.81
Ankle angel at Toe off (^{0})	10	120.00	138.00	132.90	5.22
Stature (cm)	10.00	165.00	182.00	171.20	5.01
Shoulder width (cm)	10.00	41.00	50.00	45.50	2.68
Upper limb length (cm)	10.00	78.00	90.00	81.20	3.85
Lower limb length (cm)	10.00	90.00	101.00	96.50	3.41
Foot length (cm)	10	24.00	32.00	26.70	2.31

The mean values presented in Table 1 show an average speed of 3.43 m/s which paint an exact image how the elite race walkers in the nation stride forward at speeds approaching 12.35 kph. The mean aerobic capacity of the race walker which is very relevant with the long distance event (10 km) found 55.62 ml.kg^{-1}.min^{-1}.

Race walkers were having flight phase with the mean timing of 0.07 sec and average 22.04 cm flight distance.

Whereas, mean knee angle at heel contact and mid stance phase 180.70^0 & 185.60^0 which show a hyper extended knee that results hindrances in race walk performance as always athletes have to overcome excess angle. The stature (mean = 171.20, = $\pm$ 5.01) of the athlete is perfectly proportionate with limb length; specially lower limb that is very important to gain top velocity. Trowbridge (1981) reported based on mathematical modeling, considered leg limb length the key factor determining maximum speed achievable by a race walker. Based on mathematical modeling, considered leg limb length the key factor determining maximum speed achievable by a race walker.

Table 3: Coefficient of Correlation between velocity and VO_2 max

Correlations			
		Ave. Velocity	VO_2 Max
Ave. Velocity	Pearson Correlation	1	.725*
	Sig. (2-tailed)		.018
	N	10	10
VO_2 Max	Pearson Correlation	.725*	1
	Sig. (2-tailed)	.018	
	N	10	10
* Correlation is significant at the 0.05 level (2-tailed).			
** Critical value at 8 df **r** = 0.632			

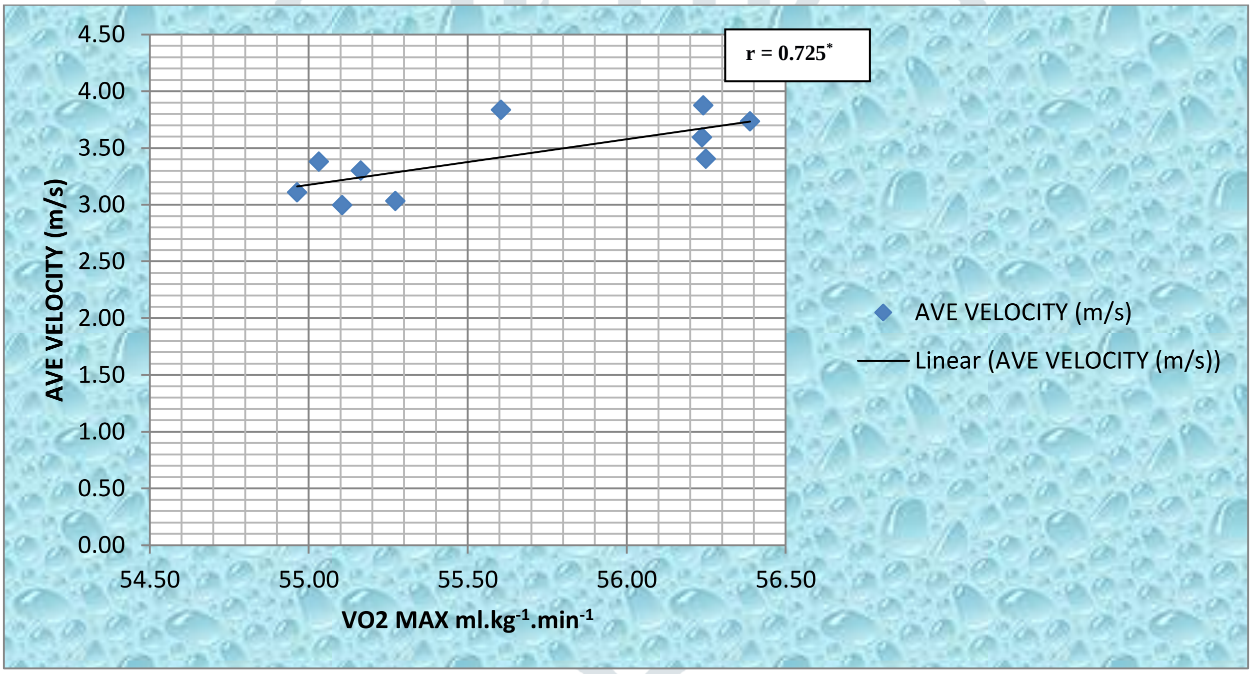


Figure 1: The relationship between velocity and VO_2max for top 10 finishers

The result of the study showed that the association between race performance and VO_2 max was quite high and a significant positive linear relationship founded with the performance (**r** (8df) = 0.726). Maximum oxygen consumption for top athletes 60-80 $ml.kg^{-1}.min^{-1}$. as compared to untrained people (35-45 $ml.kg^{-1}.min^{-1}$.) is nearly closer. In a study carried out by Martin et. Al. 2011, showed that race walkers were prevailing average 70 $ml.kg^{-1}.min^{-1}$. VO_2 max which confirms the high aerobic performance and capacity.

Table 4: Coefficient of Correlation between kinanthropometric variables and walking velocity

Correlations							
		Ave. Velocity	Stature	Shoulder width	Upper limb length	Lower limb length	Foot length
Ave. Velocity	Pearson Correlation	1	.650*	.683*	.110	.741*	.670*
Stature	Pearson Correlation	.650*	1	.887**	.591	.749*	.985**
Shoulder width	Pearson Correlation	.683*	.887**	1	.399	.749*	.853**
Upper limb length	Pearson Correlation	.110	.591	.399	1	.482	.606
Lower limb length	Pearson Correlation	.741*	.749*	.749*	.482	1	.726*
Foot length	Pearson Correlation	.670*	.985**	.853**	.606	.726*	1
*. Correlation is significant at the 0.05 level (2-tailed).							
**. Correlation is significant at the 0.01 level (2-tailed).							
***Critical value at 8 df **r** = 0.632							

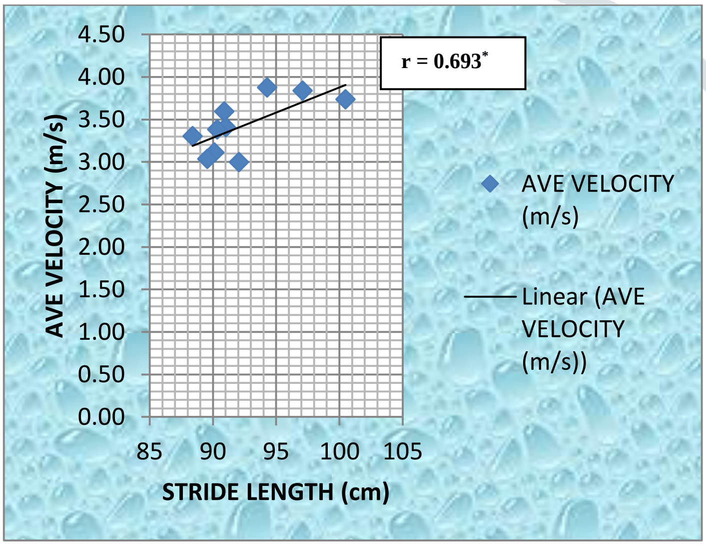
Table 4.depicted a strong positive association with various measures, i.e. stature, limb length shoulder width and foot length with walking velocity. The present study of kinanthropometric measures were significantly correlated and assisted the walking performance. Franklin et al., 1981; Ruhling & Hopkins, (1990) stated that Race walkers have similar anthropometric characteristics taller race walkers have longer step lengths which positively effects in walking speed.

Table 5: Correlation of performance with the different kinematic (Linear) variables

Correlations									
		Ave. Velocity	Stride length	Flight distance	Flight time	Torso displacement	Pelvic displacement	Max. Foot height of swing leg	Max. Knee height of swing leg
Ave. velocity	Pearson Correlation	1	.693*	-.292	.191	.770**	.804**	.015	.455
Stride length	Pearson Correlation	.693*	1	-.310	-.048	.621	.861**	-.205	.304
Flight distance	Pearson Correlation	-.292	-.310	1	.339	-.458	-.197	-.063	-.371
Flight time	Pearson Correlation	.191	-.048	.339	1	.236	.141	.000	-.088
Torso displacement	Pearson Correlation	.770**	.621	-.458	.236	1	.796**	.037	.599

Pelvic displacement	Pearson Correlation	.804**	.861**	-.197	.141	.796**	1	-.312	.200
Max. Foot height of swing leg	Pearson Correlation	.015	-.205	-.063	.000	.037	-.312	1	.626
Max. Knee height of swing leg	Pearson Correlation	.455	.304	-.371	-.088	.599	.200	.626	1
* Correlation is significant at the 0.05 level (2-tailed).									
**. Correlation is significant at the 0.01 level (2-tailed).									
** Critical value at 8 df **r** = 0.632									

Figure 2: Flight phase and stride length of the athletes participated 2017 Junior National Athletic championships



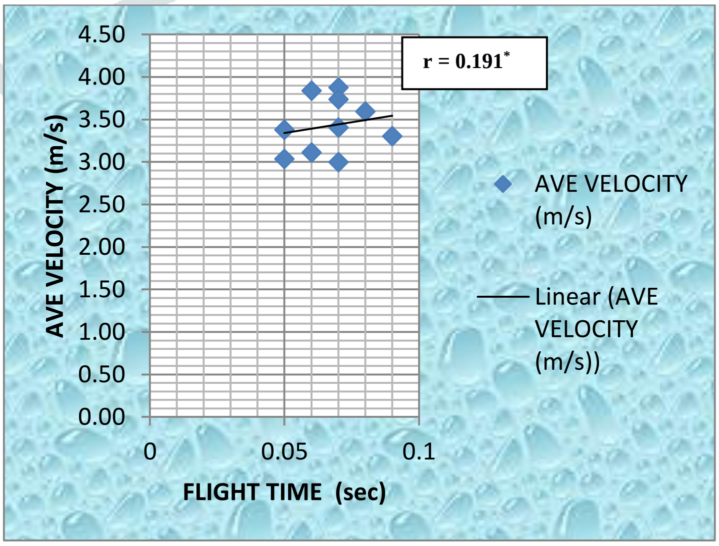
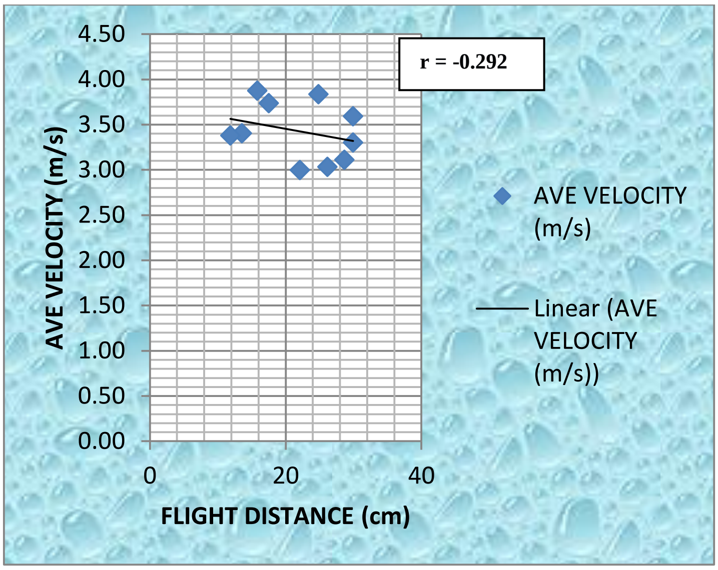


Figure 3: Relationship between velocity & stride length **Figure 4:** Relationship between velocity & Flight time



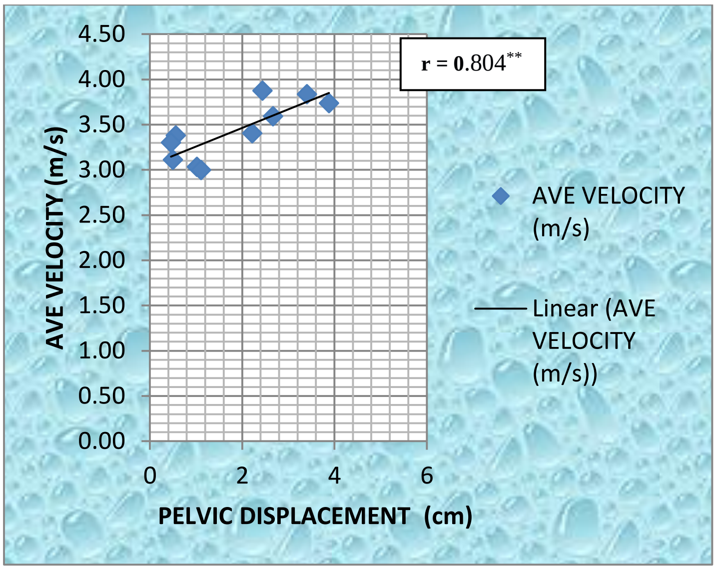


Figure 5: Relationship between velocity & flight dis. **Figure 6:** Relationship of velocity & pelvic displacement.

From the above result a strong relationship was found between step length and RW performance, i.e. **r** (8df) = 0.689. Stride length is often considered to be the more important (HOGA et al., 2003), and is affected by factors including leg length and the range of movement of the pelvic girdle. Stride frequency is determined by the time taken to complete each successive step, and as a result a shorter step time (usually the result of a shorter contact time) is associated with higher walking speeds (CAIRNS et al., 1986).

Whereas variables like, flight time, linearity, maximum knee and foot height of swing leg were positively correlated with the walking performance. De Angelis and Menchinelli (1992) analyzed 14 km·h−1 (just in the limit of what is perceptible to the human eye). Similarly, Hanley, Bissas, and Drake (2011) observed flight times of 0.03 ± 0.01 s in competition. These results are in line with the values observed in this study (0.01 ± 0.07 s), suggesting that world-class race walkers can compete at fast speeds without a visible loss of contact with the ground (Figure 3). This finding suggests that the most economical race walkers are those exhibiting shorter flight times at a given speed, resulting in a safer race walking technique in terms of risk of disqualification. The flight time has been detected in several studies and its duration (0.01–0.05 s) varied with speed (Cairns, Burdett, Pisciotta, & Simon, 1986; Cavagna & Franzetti, 1981; De Angelis & Menchinelli, 1992; Hanley, Bissas, & Drake, 2011a, 2011b; Neumann, Krug, & Gohlitz, 2006, 2008; Phillips & Jensen, 1984). In race condition, Hanley et al. (2011a, 2011b) found a flight time of 0.03 s 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). It should be noted that judges could not detect such short flight durations due to psychophysiological limitations of vision (Cairns et al., 1986; De Angelis & Menchinelli, 1992; Phillips & Jensen, 1984).

A high degree positive association was located in the torso and pelvic displacement(**r** = 0.768 & 0.804).

Table 6: Correlation of performance with the different kinematic (Angular) variables

Correlations										
			Ave. Velocity	Leanerity	Knee angel	Ankle angel	Knee angel	Ankle angel	Knee angel	Ankle angel
Ave. Velocity		Pearson Correlation	1	.417	-.491	.634*	-.408	-.302	.741*	.119
Leanerity		Pearson Correlation	.417	1	-.074	.807**	.095	-.104	.522	.033
Knee angel	Heel contact	Pearson Correlation	-.491	-.074	1	-.274	.893**	.818**	-.027	-.098
Ankle angel	Heel contact	Pearson Correlation	.634*	.807**	-.274	1	-.051	-.373	.516	.286
Knee angel	Mid stance	Pearson Correlation	-.408	.095	.893**	-.051	1	.612	.039	-.210
Ankle angel	Mid stance	Pearson Correlation	-.302	-.104	.818**	-.373	.612	1	.164	.051
Knee angel	Toe off	Pearson Correlation	.741*	.522	-.027	.516	.039	.164	1	-.136
Ankle angel	Toe off	Pearson Correlation	.119	.033	-.098	.286	-.210	.051	-.136	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

*** Critical value at 8 df **r** = 0.632

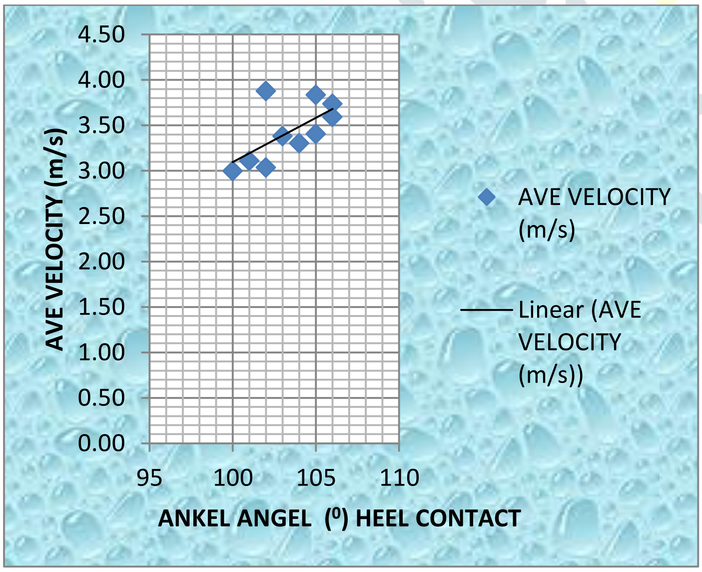


Figure 7: Relationship between velocity & ankle angel.

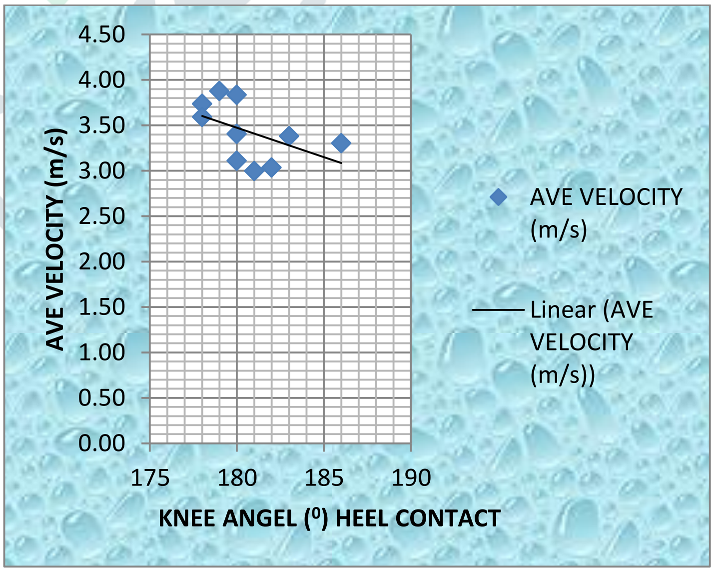


Figure 8: Relationship of velocity & knee angel.

Table 5 shows a high degree coefficient of correlation in toe off phase (**r** = 0.742) between knee angle & RW performance. Whereas at heel contact and mid stance phase a low degree negative correlation found (**r** = -0.489 & -0.406). The knee 'constraint' was highlighted in the studies after 1995, where the lower limb was straightened at heel strike (Hanley et al., 2011a, 2011b; Neumann et al., 2006, 2008; Zhang & Cai, 2000) and the knee hyper extended for almost the 70% of the contact time, with a peak at mid stance of about 10° (Donà, Preatoni, Cobelli, Rodano, & Harrison, 2009). High degree positive relationship found in ankle angle in heel contact other than rest two phases i.e. **r** = 0.637. Most of the calculated "**r**" values were significant as the critical value of 8 df at 0.05 level is 0.631. Due to the direct association of race walking velocity with VO_2 max, step length, knee angle, torso & pelvic displacement may be this type of result found in different phases. There is a direct link between the position of the foot and the joint angles of the entire leg. First, the hip angle will determine how far in front or behind the body the foot is placed. Increasing hip extension velocity results in a decrease in support time (LAFORTUNE et al., 1989), which in turn allows for much longer strides to be taken. Second, the knee is in many regards the most important joint to analyze during race walking as it is the only joint to which specific technical rules are applied. Although an extended knee is abnormal during normal walking or running, research has shown that a straight knee at landing is of benefit to race walkers (CAIRNS et al., 1986). Finally, the angle of the ankle at different points in the support phase is important: at initial contact for ensuring a straightened knee and at toe-off as its plantar-flexion aids the drive phase of the step (WHITE & WINTER, 1985).

Conclusions

In summary, Racewalking performance was positively associated with the race walking economy (kinematic kinanthropometric & physiologic variables), which implies that the fastest race walkers were more economical than the lesser performers. In relation to RW technique and forward propulsion, displacement of torso and pelvic region observe a significant role. Similarly, race walking performance and technique were related to joints angel at the different phases of the gait cycle (Support phase i.e. Heel contact, Mid stance & Toe off) and swing time, Although an extended knee prevailed during race walking that has shown a straight knee at landing is of benefit to race walkers which highlights the importance of race walking biomechanics for elite competitors in this sport. In this regard, shorter flight times (below of what is perceptible for the human eye) and longer flight distance may reduce the aerobic capacity of race walking in world-class race walkers. Similarly, taller athlete along with longer limb length proportionately aid in walking economy. Since the rules of the sport penalize a visible lost of contact with the ground, coaches and race walkers should avoid modifying their race walking style by increasing flight times, as it may not only impair economy, but also lead to disqualification.

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