THE EFFECTS OF FATIGUE ON RACE WALKING TECHNIQUE

Brian Hanley[1] and Andi Drake[2]

[1]Carnegie Research Institute, Leeds Metropolitan University, Leeds, UK
[2]Department of Physiology and Sport Science, Coventry University, UK

The purpose of this study was to measure the effects of fatigue on gait parameters during race walking. Research has shown that fatigued athletes require gait alterations in order to maintain speed. Eighteen competitive race walkers walked either 5 km or 10 km at a pace equivalent to 105% of their season's best time. Junior athletes walked 5 km, while senior athletes (mostly 20 km walkers) walked 10 km. Kinetic data were collected using a Gaitway treadmill (1000 Hz). Data were collected at three points during the 5 km walks and at four points during the 10 km walks. Repeated measures ANOVA showed that there were significant differences in impulse and contact time parameters ($p < .01$). The kinetic and temporal changes occurred as early as 1 km. Athletes are recommended to race at a constant pace to reduce the effects of fatigue.

KEY WORDS: race walking, fatigue, force, Gaitway treadmill.

INTRODUCTION:

Previous research has shown that success in race walking is related more to the efficiency of technique rather than physiological factors (Hoga *et al*., 2003). The correction and optimisation of technique is therefore of great importance to the athlete. Modifications in gait patterns may affect the energy cost of walking (Brisswalter *et al*., 1998) and these modifications can be caused by fatigue. Brisswalter *et al*. (1998) found that although fatigue caused individual walkers to alter their gait in order to maintain speed, they managed to do so without breaking the rules specific to race walking. The altering of kinematic variables during competition will affect physiolgical output (and vice versa). Drake *et al*. (2005) found that race walking economy was correlated with vertical oscillation of the centre of mass and step length, although it is not known if economy affects overall performance.

METHOD:

Eighteen national and international race walkers gave informed consent and the study was approved by the University's ethics committee. Of the athletes, seven were 20 km walkers. Five were male (mean age was 29 yrs (± 7), stature 1.81 m (± .08), and mass 70.1 kg (± 5.6)) and two were female (mean age was 21 yrs (± 1), stature 1.66 m (± .03), and mass 54.1 kg (± 1.7)). The other 11 walkers raced over 10 km and comprised seven men and three women. The seven men had a mean age of 16 yrs (± 1), stature 1.79 m (± .07), and mass 65.5 kg (± 12.1) and the four women had a mean age of 17 yrs (± 1), stature 1.67 m (± .03), and mass 58.3 kg (± 4.8). All participants were free from injury. Each athlete who normally raced over 20 km walked for 10 km on a treadmill (Gaitway, Traunstein) at a pace that resulted in a walking time equivalent to 105% (± 2) of their season's best time. Junior athletes who normally raced over 10 km walked on the treadmill for 5 km. Each athlete walked at a constant pace for the duration of the test. Kinetic data were recorded using the Gaitway treadmill, which has two in-dwelling force plates (Kistler, Winterthur). The sampling rate was 1000 Hz. Data were collected for thirty seconds at three times during the 5 km walks and four times during the 10 km walks. Data collection began at a calculated time that resulted in the midpoint of data collection coinciding with 1000 m, 2500 m, and 4500 m (for the 5 km walkers) and 2500 m, 4500 m, 6500 m, and 8500 m (for the 10 km walkers). As well as kinetic data, the associated software (Gaitway, Traunstein) gave values for step length, cadence, and temporal data. In order to measure the effects of fatigue on the values obtained from the kinetic data, statistical analysis consisted of repeated measures ANOVA with post hoc tests using Bonferonni adjustments.

RESULTS:

Table 1 shows the results for the forces at impact peak and active peak, as well as the weight acceptance and push-off rates. Impact peak is defined as the highest recorded force during the first 70 ms of contact with the treadmill; midsupport is defined as the minimum force value recorded between the weight acceptance and active peaks; while the maximum force occurred in all cases during the active peak. Only vertical ground reaction forces are displayed as it is not possible to record shear forces with the treadmill. Weight acceptance is the slope of the force curve during the loading phase, taken from the point of 10% of the impact peak force to the point of 90%; while the push-off rate is the slope of the force curve during unloading, taken from the point of 90% of push-off peak force to the point of 10%.

Table 1 Force Data and Loading Rates at Each Distance (mean ± SD)

Distance	Impact peak (N)	Maximum (active) (N)	Wt. acceptance (N/s)	Push-off rate (N/s)
Juniors				
1000 m	905 (± 130)	1090 (± 195)	20205 (± 4745)	9920 (± 2475)
2500 m	925 (± 150)	1100 (± 185)	19875 (± 5100)	9755 (± 2375)
4500 m	905 (± 165)	1095 (± 190)	19325 (± 4720)	9940 (± 2220)
Seniors				
2500 m	970 (± 190)	1155 (± 205)	20220 (± 3875)	9630 (± 2635)
4500 m	1000 (± 165)	1160 (± 195)	19740 (± 3395)	9280 (± 2060)
6500 m	975 (± 175)	1145 (± 195)	19750 (± 3370)	9605 (± 2785)
8500 m	980 (± 165)	1140 (± 170)	19205 (± 3755)	9215 (± 2195)

Impact forces remained relatively constant throughout the walks for both the senior and junior athletes. Maximum forces decreased as the walks progressed in the senior walkers, although this decrease was not replicated in the juniors, and was not significant. Although overall weight acceptance rates and push-off rates decreased during the walks, no significant differences were found for these variables.
Walking speed is the product of step frequency (cadence) and step length. The values for these measurements, as well as base of support and impulse, are shown in Table 2 below. When expressed as a percentage, step length was on average 60% of overall stature, with a range between 57 and 68%.

Table 2 Cadence, step length, base of support, and impulse (mean ± SD)

Distance	Cadence (Hz)	Step length (m)	Base of support (mm)	Impulse (N.s)
Juniors				
1000 m	3.09 (± .16)	1.04 (± .07)	32 (± 17)	199 (± 37)
2500 m	3.09 (± .15)	1.04 (± .08)	32 (± 14)	197 (± 36)
4500 m	3.10 (± .15)	1.04 (± .08)	32 (± 13)	193 (± 36)
Seniors				
2500 m	3.13 (± .14)	1.11 (± .10)	25 (± 13)	205 (± 33)
4500 m	3.11 (± .14)	1.11 (± .10)	25 (± 16)	203 (± 32)
6500 m	3.11 (± .14)	1.11 (± .10)	26 (± 14)	201 (± 32)
8500 m	3.09 (± .14)	1.12 (± .10)	29 (± 20)	200 (± 32)

Cadence and step length remained consistent throughout the walk, as did the base of support. No significant differences were found for these variables. However, impulse (in the vertical direction) did decrease significantly both for the junior athletes (F = 27.3, p < 0.01, eta^2 = .73, power = 1.00) and the seniors (F = 17.1, p < 0.01, eta^2 = .74, power = 1.00). The post hoc tests showed that the values for impulse decreased significantly between each stage for the juniors, and that for the seniors there was a significant decrease between the values at 2500 m and 4500 m and those at 6500 m and 8500 m. Cadence is determined by the time taken to complete each successive step. The mean step time for the junior athletes was .33 s (± .01) at all four stages. Contact time decreased continually as the walk progressed from .286 s (± .03) at 1000 m to .276 s (± .03) at 4500 m. This decrease was significant (F = 34.4, p < 0.01, eta^2 = .78, power = 1.00), and the post hoc tests showed significant differences between each stage. Furthermore, the proportion of step time spent in contact with the treadmill also changed significantly (F = 50.5, p < 0.01, eta^2 = .84, power = 1.00), decreasing from 88.0% of total step time at 1000 m to 86.5% at 4500 m. This led to an increase in flight time from .039 s (± .01) at 1000 m to .047 s (± .02) at 4500 m. This is shown in Figure 1. The mean step time for the senior athletes was .32 s (± .01) at all four stages. Contact time increased negligibly as the walk progressed from .285 s (± .02) at 2500 m to .286 s (± .02) at 8500 m.

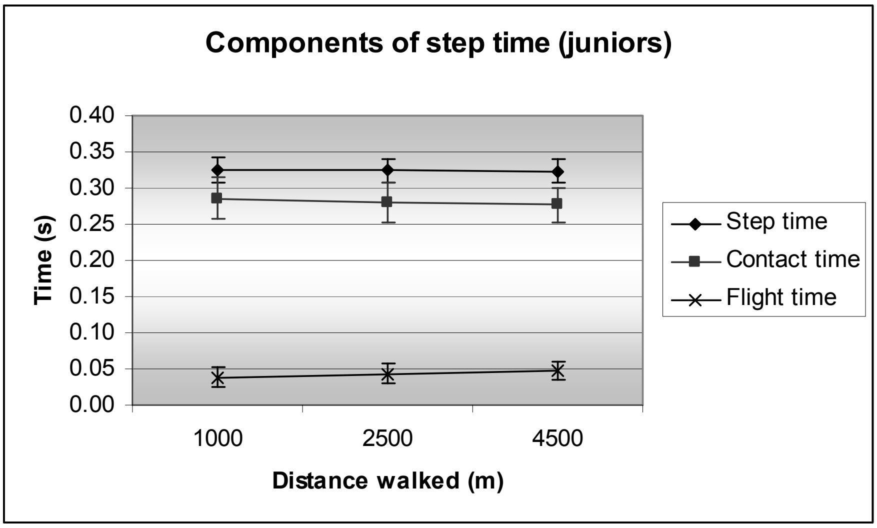

Figure 1: The mean values for step time, contact time, and flight time (s) for the junior athletes.

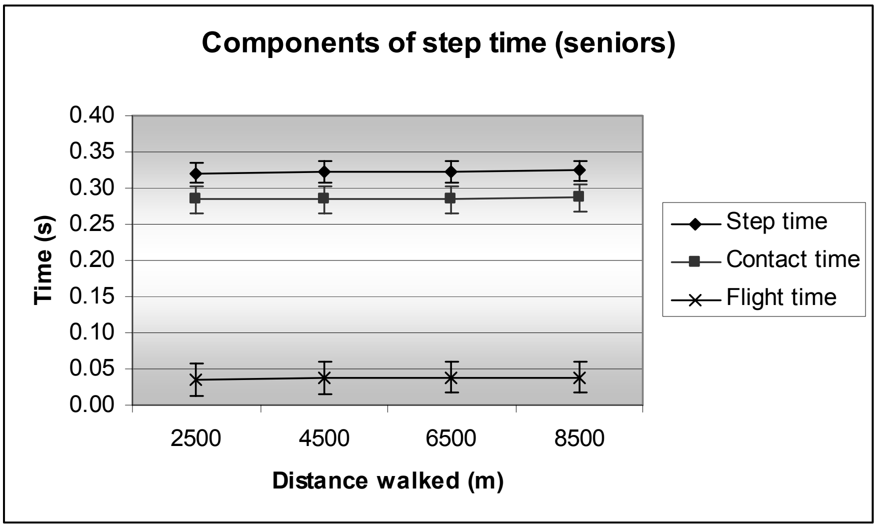

Figure 2: The mean values for step time, contact time, and flight time (s) for the senior athletes.

DISCUSSION:

There were a number of changes evident in the kinetic and kinematic parameters measured during the course of the walk. Because the normal response to fatigue of simply reducing walking speed was not available to the athletes, other responses were necessary in order to overcome tiredness. Although not statistically significant, the senior athletes did increase step length slightly during the walk by .01 m, with a corresponding decrease in cadence. Although overall step time remained stable throughout the walk, the percentage of time spent by the junior athletes in contact decreased by 1.5%. It would seem that the response of race walkers to fatigue is to 'lift' in order to maintain walking speed. Corresponding decreases in parameters such as force production and push-off rate did not occur, although impulse (in the vertical direction) did do so, showing the effect of decreasing contact time.

The differences in vertical impulse that were found to be significant occurred as early as the 1000 m point in the junior athletes, and at approximately half-way in the seniors. Of more importance was how early (after 1000 m) the junior athletes increased their flight times to a duration where disqualification would be probable. Although the athletes could not slow down as in a normal race situation, the speeds they were walking at were slightly slower than their best race times and therefore were not unusual for them. The effects of fatigue are therefore exhibiting themselves very early during a fast walk, and it could be assumed that they would exhibit themselves even earlier during an actual race, as it is not unusual for many athletes to walk the first few kilometres of a race faster than the remainder. The athletes in the present study walked at a constant pace and their results do not show great changes in step length and cadence. This supports the notion that it is best to race walk at a constant pace, from both a physiological and biomechanical point of view.

A limitation of using the Gaitway treadmill is its inability to record shear forces; thus it is not possible to measure important variables which may have changed due to fatigue (e.g. propulsive anterio-posterior forces). So, while maximum vertical impulse decreased as the walk progressed, it is possible that horizontal propulsive impulse increased in order to maintain horizontal speed. Although most athletes were experienced at walking on treadmills, it is an artificial setting in comparison with track or road walking and therefore it is not certain that the athletes adopted their normal walking technique. Further studies investigating the effects of fatigue in natural outdoor race conditions are warranted.

CONCLUSION:

The gait parameters which changed significantly during 5000 m and 10000 m treadmill walks were impulse, contact time, and proportion of time spent in contact. Fatigue was shown to have an effect on important gait parameters as early as 1000 m in junior athletes, and these effects may be amplified in a faster race situation. Athletes and coaches should be aware that the maintenance of efficient walking technique is crucial to successful racing performances and the reduction of risk of injury. A constant pace during racing and training (as appropriate) will possibly reduce the effects of fatigue and delay the stage at which they occur. Athletes should also train to maintain efficient walking posture using strengthening, stabilising, and functional movement exercises.

REFERENCES:

Brisswalter, J., Fougeron, B., and Legros, P. (1998). Variability in energy cost and walking gait during race walking in competitive race walkers. *Medicine and Science in Sport and Exercise*, 30(9):1451-1455

Drake, A., Cox, V., Godfrey, R., James, R., and Brooks, S. (2005). Race walking economy of highly trained race walkers (abstract). *Journal of Sports Sciences*, 23(2):199-200

Hoga, K., Ae, M., Enomoto, Y., and Fujii, N. (2003). Mechanical energy flow in the recovery leg of elite race walkers. *Sports Biomechanics*, 2(1):1-13