A KINEMATIC COMPARISON OF THE RUN-WALK TRANSITION AND ULTRA-MARATHONERS

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The purpose of this study was to compare four kinematic variables seen as part of the run-walk transition with those same variables measured in runners of a 100km race. The sagittal kinematics of six elite, male, ultra-distance runners were analyzed from an equidistant point throughout the race. Vertical oscillations as measured from the greater trochanter and trunk, thigh and shank segment angles, from horizontal, were all measured and compared to patterns noted in previous literature. When compared it was observed that the 100km runners show significant results on at least one of the variables, meaning that some measured kinematics begin to show the signs of gait transition from a run to a walk.

KEY WORDS: ultra-distance, kinematics, gait transition, running

INTRODUCTION: In this new millennium we are seeing athletes pushing their bodies to new limits in the pursuit of glory in extreme sporting events. To this point, the majority of studies done on such athletes have been in the physiological domain, none focusing solely on the biomechanics of these athletes. As well, the standard distance of a marathon, 42.2km, has not been surpassed when investigating the kinematics of running gait. The subjects in the present study were all finishers of the International Association of Ultrarunners (IAU) 100 kilometer World Challenge under the patronage of the International Amateur Athletic Federation (IAAF). It is reasonable to assume that some kinematic breakdown occurs in conjunction with the physiological affects of running such a distance. The extent of this kinematic breakdown remains unexplored. This study attempts to compare the similarities that exist between the kinematics of the run-walk transition and the degeneration of the gait pattern of these ultra runners. From direct observations, Thorstensson and Roberthson (1987) noted a transition in gait patterns to be an adaptation to speed as a result of changes in both the amplitude and frequency of leg movements. This phase of gait transition is seen as a distinct event that can be described through various kinematic patterns (Diedrich & Warren, 1995; Farley & Ferris, 1998). Candau et al. (1998) noted that during a fatigued run, the mean height of the center of gravity at the point of contact decreases. In terms of economical gait patterns, Anderson (1996) and Williams, et al (1987) both related a greater maximum hip extension angle and a smaller knee angle at toe-off to more efficient gaits. When relating these studies to the studies on the walk-run and run-walk transition, Hreljac (1995) described an abrupt decrease in maximum hip extension angle that accompanied the transition from and walk to a run. Interestingly, individuals running in a fatigued state have been noted to run in an almost seated position, compensating for lower body stiffness by stretching their leg extensors (Candau et al., 1998). One can then postulate that during the transition, due to fatigue, from a run to a walk the maximum hip extension angle will display increased values. It has also been noted that elite distance runners display more efficient kinematics in the latter stages of a race. Anderson (1996) concluded that the elite runners, when compared to the “good” runners, were able to maintain a nearly erect trunk. The possible applications of this study may included modification of training and race strategy, and if teamed with the breadth of knowledge in the physiological aspect of such events, faster and more efficient racers.

The purpose of this study was to start quantifying the kinematics of an ultra marathon with special attention being given to highlighting the kinematic variables that mimic those that have been observed during a run-walk transition.

METHODS: The top six male finishers of the 100km ultra marathon, who were between 20 and 39 years of age, were videotaped from a sagittal view at a stationary point 15.0 meters from the end of the 10-kilometer loop. A field of view 2.4 meters in length was captured. Each subject completed the race and was captured on video, between 7-10 times. Data was gathered using a JVC Cybercam 9800 digital video camera, recording at 60 Hz with a shutter speed of 1/250. Each portion of the stride that was filmed in the 2.4-meter area was analyzed using the Ariel Performance Analysis System (APAS). The approximate positions of the tubercle of the humerus (estimated joint center of the shoulder), the greater trochanter of the femur (estimated joint center of the hip), the lateral epicondyle of the femur (estimated joint center of the knee), lateral malleolus, heel, and the fifth metatarsal head were all determined and manually digitized. Data was then smoothed using a fourth order, zero-lag Butterworth digital filter with cut-off frequencies ranging generally between 6 to 8 Hz. The smoothed data was then used to acquire the kinematic measures of interest; specifically the vertical oscillations of the estimated center of gravity, taken as the greater trochanter of the femur and the trunk, thigh and shank segment angles. Segment angles were measured with respect to the horizontal. The statistical analysis performed on the data was a repeated one-way analysis of variance, with a Tukey post-hoc to determine the critical value.

RESULTS: After performing repeated one-way analysis of variances on each of the four kinematic variables it was found that there were no significant differences of the means for the group between the first 10km and the final 10km.
Table 1 displays the means and standard deviations of each variable for the six subjects at each of the five distances analyzed.

Table 1 Means for Kinematic Variables as Measured at Increasing Distances over the Course of a 100km Race

Variable	10 km	50 km	70 km	90 km	100 km
Hip Vertical Displacement cm	10.7 ± 2.4	11.4 ± 1.8	10.2 ± 2.4	10.6 ± 1.6	10.9 ± 1.8
Trunk Angle ROM degrees	19.6 ± 2.5	18.3 ± 4.5	20.7 ± 2.7	19.7 ± 5.0	17.8 ± 3.7
Thigh Angle ROM degrees	61.6 ± 19.1	65.3 ± 13.2	68.9 ± 5.6	62.1 ± 13.2	66.0 ± 17.3
Shank Angle ROM degrees	99.7 ± 13.5	97.7 ± 17.9	93.9 ± 28.6	98.8 ± 12.4	96.9 ± 19.9

Though the results were not statistically significant one measure warrants future investigation. The mean thigh segment angle was greatest, with the lowest standard deviation at the 70km distance. At this same point in the race the mean shank segment angle was the least, but with the highest standard deviation. This may be an indication of segment compensation, and would benefit from further study.

DISCUSSION: Statistical analysis of the data suggested that no differences were apparent between subjects over the course of the race on the four walk-run transition variables. Race times for the six subjects ranged between 6:25:38 and 7:09:30 (hrs:min:sec). It was hypothesized that an event of this duration would be accompanied with an observable alteration in gait pattern similar to pattern changes reported due to fatigue or during run to walk transitions. Siler and Martin (1991) reported statistically significant increases in thigh range of motion, maximum thigh and knee flexion angles, and decrease in maximum extension angles during a fatigued run. Excessive vertical oscillation of a runners center of mass is commonly associated with inefficient running patterns, surprisingly there have been few studies investigating this hypothesis. Cavanagh et al. (1977) did report that elite distance runners had slightly smaller, though nonsignificant, vertical amplitudes of their center of mass when compared to good runners. Typically transitions occur at speeds that will lead to more comfortable locomotion situations (Thortensson & Roberthson, 1987). As well this same study indicated that elite runners display more acute knee angles during swing than non-elite runners do. The apparent lack of change in running pattern between progressive observations is testimony to the efficiency and adaptability of the human engine or more simply to the level of cardiovascular and muscular fitness of these top competitors. The average lap time difference between the first and last lap was a mere 42 seconds. The data also suggests that interpretation of this seemingly invariant gait pattern would not be subject to a run-walk transition assessment. However, temporal information of the last place finishers suggests that comparison to these top six finishers is warranted.

CONCLUSION: From the results we can conclude that neither of the four kinematic variables, vertical oscillation, trunk, thigh or shank angles with horizontal, for the top six finishers, were found to have statistically significant changes when comparing them at the beginning and at the end of a 100km race. This refutes the hypothesis presented, that running gait would display fatigue induced alterations in kinematics that mirrored those seen as part of a run-walk transition. As there were no significant changes in any of the four variables, one can conclude that extreme athletes have proven they are mechanically capable of pushing themselves to new limits. Future research would benefit by focusing on the kinematic breakdown of gait, specifically the mechanical limits that humans have yet to reach. Results of such studies could be teamed with physiological research to help expand the capabilities of the extreme athlete.

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