PHASE DIFFERENCE BETWEEN FORWARD SWINGS OF THE UPPER AND LOWER LEGS IN LONG DISTANCE RUNNING

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In previous observations of the lower extremity movement in long distance running, a seemingly ineffective action, was noticed. It was observed that the upper leg swung to its most forward angle once, then returned backward before the lower leg swung to its most forward angle, prior to the foot touching the floor (Kawai & Hiki, 1999). In this study, the relationship between the phase difference and the amount of work around the hip joint was investigated, by using a computer simulation, in order to determine the meaning of the phase difference. From the results, it was reasoned that the upper leg swung forward in the advanced phase before the lower leg. This was in order to decelerate the mass of the lower leg smoothly, by raising the knee and to minimize the change of work for decelerating the whole leg before the foot touching the floor.

KEY WORDS: long distance running, hip joint, knee joint, angular velocity, work, computer simulation

INTRODUCTION: In a previous study, the loci of the lower extremity joints were traced in the video pictures of long distance runners, and the relationship among rotating angles around the joints was examined. An intriguing relationship between the forward swings of the upper and lower legs was noticed in the observation.

When the lower extremity swings forward, the knee joint flexes in order to reduce the moment of inertia of the lower leg plus the foot. Then, the hip joint flexes and the knee joint extends to let the foot touch forward on the floor. A seemingly ineffective action occurred during this action, that is, the upper leg rotated to its most forward angle once, then returned backward before the lower leg rotated to its most forward angle and the foot touched the floor (Kawai & Hiki, 1999).

In this study, the relationship between the phase difference and the amount of work around the hip joint was investigated by using a computer simulation, in order to inquire the meaning of the phase difference.

OBSERVATION: Method. The lateral view of the running forms of three male college long distance runners running on a treadmill was recorded on a videotape. The running speed was 10.8km/h (3.0m/sec) and the floor slope was 0 degrees. A repetition period of the stride was set to 2/3sec.

One stride cycle of the most typical running action was converted from a video picture into computer graphics. Then, the two dimensional coordinates of the axes of rotation of the hip, knee and ankle joints, and the toe, the heel and the neck were measured.

Results. When the foot was about to touch the floor, the lower leg swung to the most forward angle and the foot touched the floor, after the upper leg had swung to its most forward angle and returned backward (Figure 1).

The hip joint angle of the maximum flexion was about fifty degrees. The backward return of the upper leg, when the lower leg swung to its most forward angle, was about ten degrees in both subjects A and B. This angle of backward return, as well as the angle of the maximum flexion, was somewhat larger in subject C. In spite of the personal characteristics of those angles, the phase advance in the forward swings of the upper leg was about 1/5 of a single stride period in all subjects.

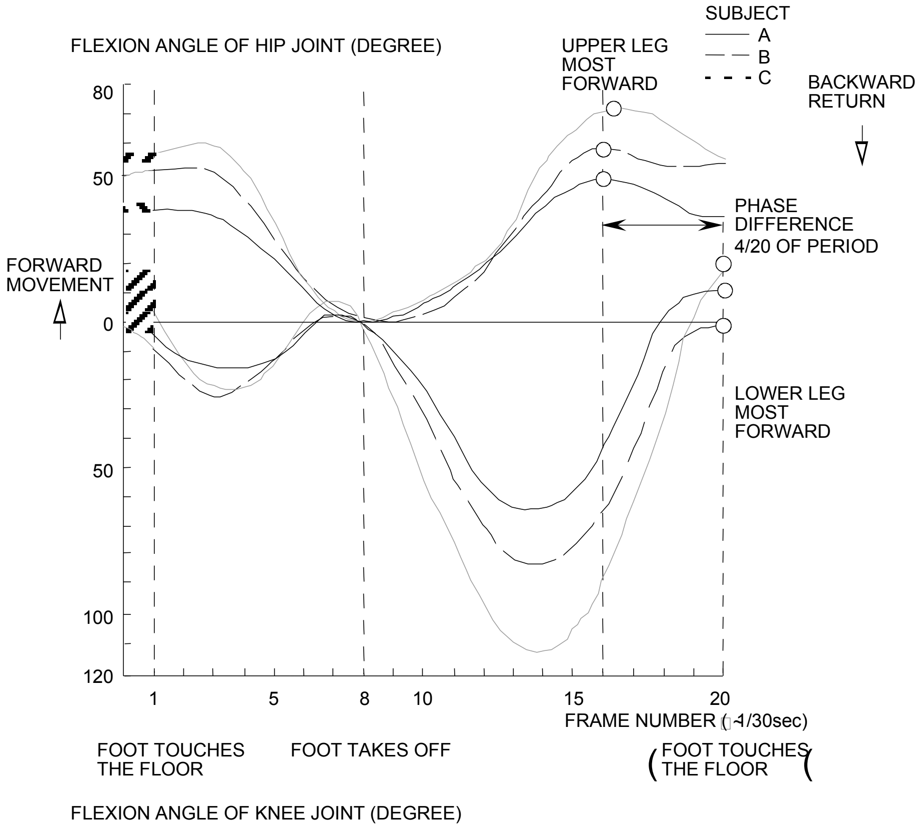

Figure 1 - Phase difference between forward movements of the upper and lower legs in long distance running.

COMPUTER SIMULATION: Method. The effect of the phase difference between forward swings of the upper and lower legs on the work around the hip joint was calculated by using a computer simulation.

By referring to the observed data of the three subjects, a typical pattern of the time change in the rotating angle of each of the joints was generated. The sinusoidal waveform from π/2 to 3π/2 radians was applied to the four sections of the hip joint rotation. The first section was the flexion for touching the floor and shock absorbing. The second was the extension for detaching the floor. The third was the flexion for forward swing, and finally, the extension for backward returning. There were also four sections of the knee joint rotation. First, the flexion for touching the floor and shock absorbing and secondly, the extension for detaching the floor. The third section was the flexion at detaching, and finally, the extension for touching the floor. The three sections of the ankle joint rotation were as follows: (1) the dorsiflexion for touching the floor and shock absorbing, (2) the plantarflexion for detaching the floor, and (3) the dorsiflexion for returning to the neutral position during flight.

The pattern of time change in the rotating angle of the hip joint was gradually modified so that it reached to the angle of the typical pattern without the backward return in the case of no phase difference (Figure 2).

On the other hand, the position of the center of mass was estimated for the change in shape of the lower extremity. First, divisions of the body were modeled as circular or conical cylinders, and the size of the each division was measured and the weight was calculated for one of the subjects. Then, by concentrating the weight of each division at the center, the centers of mass of the upper leg and the lower leg plus foot were estimated.

From those quantities, moment of inertia, angular velocity, angular acceleration, angular momentum, kinetic energy and amount of work of the upper leg and the lower leg plus foot around the hip or knee joint were derived.

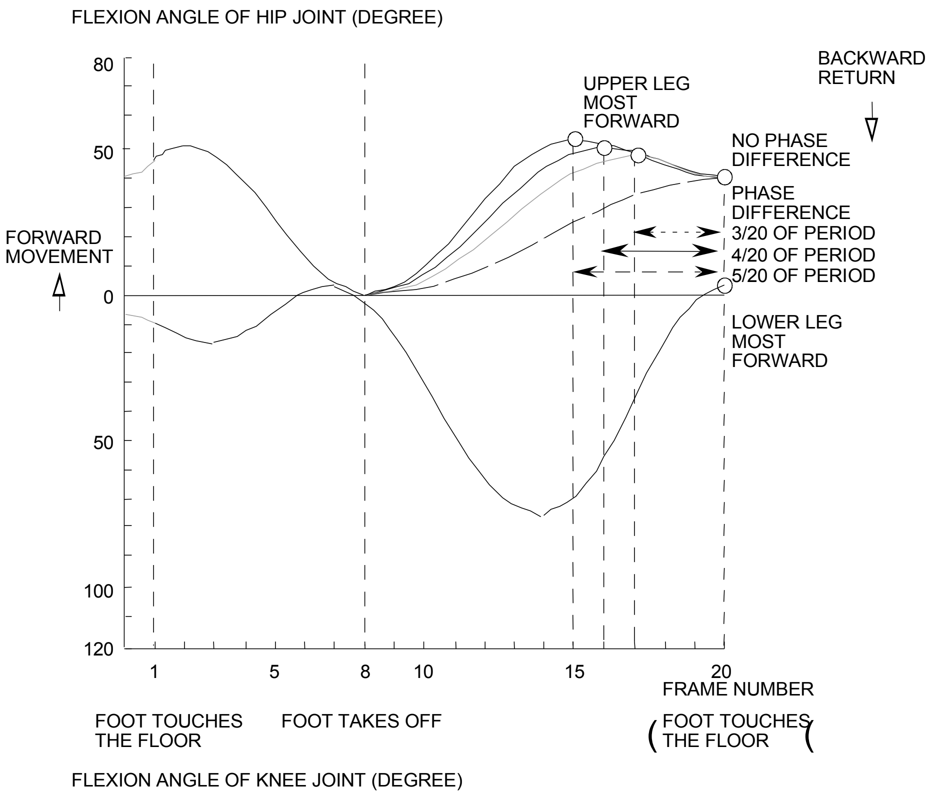

Figure 2 - Change in rotation angle of the hip and knee joints generated for a computer simulation.

Results. Synthesized stick figures in the case of the typical pattern and no phase difference were shown in Figure 3. In the case of no phase difference, the position of the center of mass of the lower leg was suddenly lowered, when the pattern of change in the knee joint angle was kept the same in each condition.

The amount of work required by rotating the lower leg around the hip joint became greater upon decelerating the angular velocity around the knee joint, before the foot touched the floor, if there was no phase difference (Figure 4). The amount of work became minimal at around the typical pattern with phase difference of 1/5 of a stride period.

DISCUSSION: This narrowing of the change in rotating velocity of the lower leg, plus foot around the hip joint, was realized. This occurred because the acceleration and deceleration of the forward rotation of the lower leg, plus foot around the knee joint, was compensated by those of the forward and backward rotation around the hip joint (Figure 5).

CONCLUSION: Based on these results and the discussion, it was concluded that the reason for the seemingly ineffective phase difference occurs is that the upper leg swings forward, in advance of the lower leg. This is done in order to decelerate the mass of the lower leg smoothly by raising the knee and to minimize the change of work for decelerating the whole leg before the foot touched the floor.

Such analysis on the mechanism of the leg action appears to be useful for achieving the most appropriate movement of the lower extremity in running against different conditions of slope, wind, pace or fatigue, as well as for preventing the deterioration of walking ability in daily life.

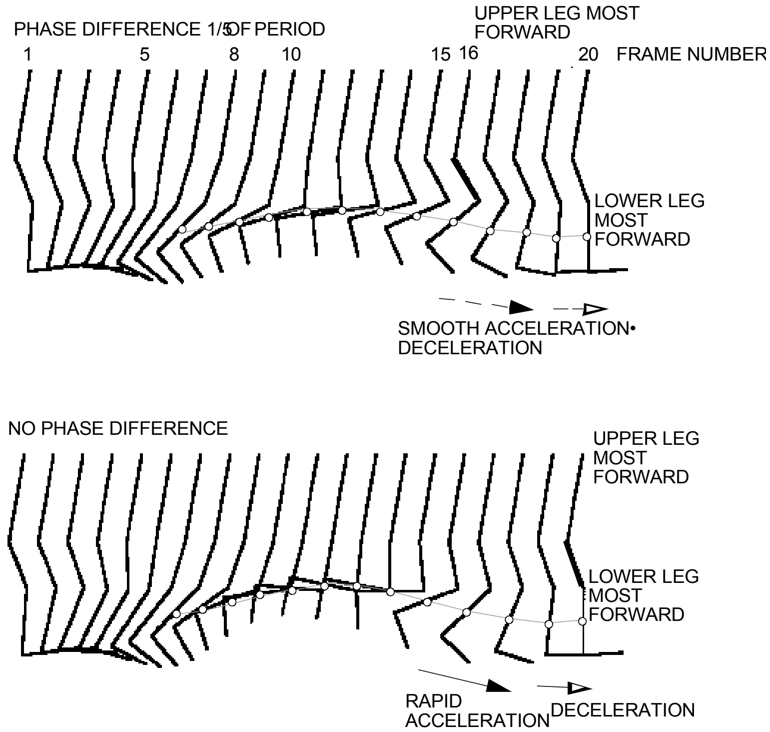

Figure 3 – Synthesized stick picture with phase difference of 1/5 of a stride period and no phase difference.

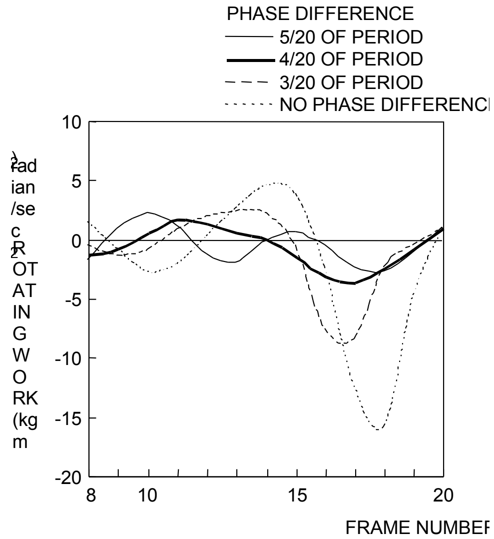

Figure 4 - Change in the amount of work required by rotating the lower extremity around the hip joint according to the phase difference in long distance running.

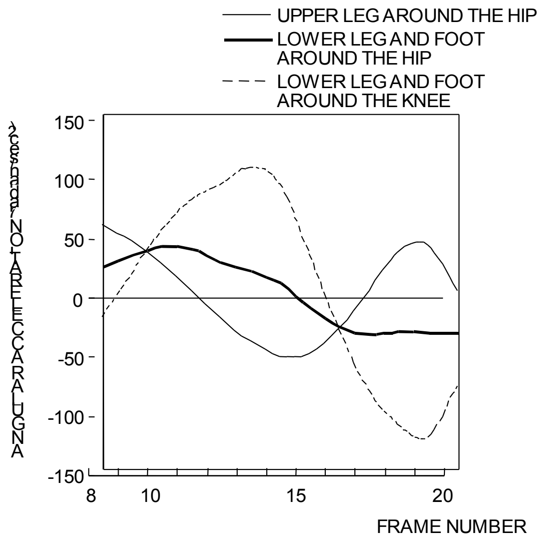

Figure 5 – Change in angular acceleration of the upper leg, and the lower leg plus foot rotting around the hip joint, and the lower leg plus foot rotating around the knee joint in phase difference of 1/5 of a stride period.

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Kawai, Hisashi, & Hiki, Shizuo (1999). Factors which reduce efficiency of actions of the lower extremities in long distance running. *Abstracts, International Society of Biomechanics XVIIth Congress*, 767.