CONTRIBUTION OF KINEMATIC VARIABLES TO RACEWALKING VELOCITY

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Several studies have investigated the kinematics and kinetics of racewalking gait. Payne (1978) compared the ground reaction forces of racewalking to those elicited during walking while Fenton (1984) compared the ground reaction forces of competitive and elite racewalkiers. Murray, Guten, Mollinger, and Gardner (1983) and Phillips and Jensen (1984) reported temporal components and angular displacement patterns of olympic and elite racewalkers. A comparison of the kinetic and kinematic parameters of walking, racewalking, and running was recently reported by Cairns, Burdett, Pisciotta, and Simon (in press).

The gait of racewalking has evolved as a result of the limitation of the rules of racewalking. In order to execute a legal gait, the forward foot of the walker must make contact before the rear foot leaves the ground and the "supporting leg must be straight in the vertically upright position" (I.A.A.F., 1984, p.162). The restraints of the rules of racewalking have produced a gait with some unique biomechanical chacteristics. Murray et al. (1983) compared temporal and angular displacement chacteristics of two olympic racewalkers to a group of men walking fast. The results indicated that the racewalkers had longer strides, faster cadences, and stance and swing times which were almost equal. The racewalkers also exhibited increased ankle dorsiflexion at heelstrike, increased knee hyperextension in midstance, increased knee and hip flexion during swing, and increased pelvic rotation. In a recent study by Cairns et al.(in press), in which the gaits of walking and racewalking of 10 racewalkers were compared, racewalking produced significantly different values in stride length; cadence; stance time; swing time; peak ankle dorsiflexion; knee extension at midstance; peak hip flexion; peak pelvic displacement in all three planes; and peak vertical, anterior, and medial components of the ground reaction force.

The seemingly exaggerated angular motions of racewalking are necessary in order to attain increased velocities within the rules of racewalking and to modulate the excursions of the center of mass. The increased vertical and anterior components of the ground reaction force are related to the increased propulsive forces associated with increased stride length and velocity in racewalking. The increased medial component of the ground reaction force seems to be a compensatory force related to lateral pelvic shifting.

The purpose of the present investigation was to identify the contribution of selected kinematic variables to the velocity attained during racewalking.

METHOD

Cinematographic and force plate data were collected from 10 competitive racewalkers. Black markers were placed over each subject's joint centers according to the protocol described by Cairns et al. (in press). Three high speed 16mm cameras were positioned anteriorly and laterally to a 40 foot walkway. A strain gauge force platform was solidly mounted into the walkway on a level with the surrounding floor and was used to record ground reaction forces under the right foot.

Each subject was filmed and force plate data were collected while subjects racewalked at a self-selected training pace and a self-selected competitive pace. Two dimensional coordinates and footstrike events were entered into a computer using a Vanguard Motion Analyzer and a Graf Pen Sonic Digitizer. From the computer stored data, temporal and angular values were calculated for specific events during the gait cycle. The significance of the difference between selected angular and temporal parameters was determined using t-tests.

RESULTS AND DISCUSSION

The means of velocity, stride length, cadence, stance time, swing time, and the ratio of stance to swing time for the training and competitive paces of racewalking are displayed in Table 1. As a group, these racewalkers increased velocity to a competitive pace with significant increases ($p<.01$) in stride length and cadence and a reduction in the ratio of stance to swing time such that the percent of the gait cycle represented by stance and swing were almost equal.

TABLE 1

MEAN VALUES OF TEMPORAL COMPONENTS OF TWO VELOCITIES OF RACEWALKING (N=10)

	Training Racewalk	Competitive Racewalk
Velocity (m/s)	2.89	3.63
Cadence (strides/s)	1.36	1.54
Stride Length (m)	2.13	2.36
Stance Time (s)	.42	.34
Swing Time (s)	.36	.34
Stance Time/Swing Time Ratio	1.15	1.02

Increases in racewalking velocity also resulted in significant increases ($p<.01$) in peak ankle dorsiflexion and hip flexion. In a previous investigation (Cairns et al.,in press), ankle dorsiflexion and pelvic rotation were identified as the means of increasing stride length as racewalking and walking were compared.

In an attempt to identify variables which may be linked to attaining maximal competitive velocities in racewalking, the racewalkers in this study were assigned to two groups based upon performance times in comparable competitive events. The means of velocity; cadence; stride length; stance time; swing time; ratio of stance to swing time; maximal angular displacements at the ankle, knee, hip, and pelvis; and ground reaction forces from the competitive racewalk trial of each group were compared. Table 2 displays the means of the chacteristics which were significantly different between the performance groups. The better racewalkers were able to attain a mean velocity of 4.07m/s with a range of 3.85 to 4.25m/sec. This velocity seems to be partially a result of greater stride length which may be related to their longer leg length. Phillips and Jensen (1984), in a study of elite racewalkers, stated that optimal technique may be in part a function of anthropometric characteristics.

TABLE 2

MEANS OF SELECTED VARIABLES WHICH DIFFERENTIATE BETWEEN TWO PERFORMANCE GROUPS OF RACEWALKERS

Variable	Performance Group 1	2
Velocity (m/s)	3.13	4.07
Stance Time (s)	.40	.40
Stance Time/Swing Time Ratio	1.14	.89
Anterior GRF (x bw)	.29	.39
Stride Length (m)	2.17	2.56
Leg Length (m)	80.06	83.82
Max Knee Extension (deg)	184.00	190.00

The better performers displayed a significantly shorter stance time resulting in a stance time/swing time ratio of less than 1.00 which is indicative of flight in the gait of racewalking. This period of flight, common among elite racewalkers would not be discernible to the human eye. The anterior component of the ground reaction force appears to be a variable which is linked to the acquisition of the greatest maximal velocity in racewalking. Increased propulsion in the forward direction without increased vertical deviation of the center of mass is a desirable characteristic which will not result in increased compensatory motion in the shoulders and pelvis. An undesired characteristic displayed to a greater degree by the better performers in this study, however, was knee hyperextension which is a function of the straight legged position required by the rules of racewalking. Knee hyperextension was also identified by Murray et al. (1983) and Phillips and Jensen (1984) in their studies of elite racewalkers.

It is interesting to note that these two performance groups of racewalkers did not differ significantly on other peak angular deviations. Further analysis of performance groups should include more subtle angular changes which immediately precede or follow the footstrike events. Murray et al. (1983) identified that elite racewalkers utilized hip extension during late swing to gain momentum to pull the body forward over the striking foot. There may be subtle angular differences such as this between the performance groups used in this study which were not identified in this analysis. In a previous study (Cairns et al., in press), increased hip and knee extensor moments were identified as being characteristic of racewalking as compared to walking. The higher velocities attained by the better performers in this study may be a function of greater extensor moments of force during stance and at push-off.

SUMMARY

It is evident from this investigation that increased stride length, an increased anterior component of the ground reaction force, and a stance time/swing time ratio which approaches 1.00 are characteristic of increased velocity and better performance times in racewalking. Further investigation is needed to identify other kinematic variables as well as kinetic variables which characterize high performance in racewalking.

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