Muscular Load of The Lower Extremity Muscles during Uphill Running

T. Yokozawa*, N. Fujii**, and M. Ae**
* Doctoral program of Health and Sport Sciences, University of Tsukuba, JAPAN
** Institute of Health and Sport Sciences, University of Tsukuba, JAPAN

INTRODUCTION

Most biomechanical studies concerning uphill running have been done on a treadmill in spite that there are some differences in the kinematic variables between treadmill running and overground running. Moreover, few studies analyzed kinetic variables of the support leg in uphill running with a force platform. The purpose of this study was to investigate effects of grade of slope on the muscular load of lower extremity muscles for overground running.

METHODS

Six distance runners were asked to run on slopes of four grades (0, 3.2, 6.4, and 9.1%) at three running speeds (3.5, 4.3, and 5.1 m/s). Subjects were videotaped with a high-speed video camera. Ground reaction forces were measured with a force platform mounted in the specially constructed runway (12m) on the slope. Two dimensional coordinates of body segment endpoints were calculated by a panning DLT method. Joint angular velocities and joint torques of the lower extremity were calculated based on a two dimensional link segment model. SIMM (MusculoGraphics, Inc., Evanston, IL) were used to calculate contraction velocities and the maximum possible forces (MPF) of twenty lower extremity muscles, and the maximum possible extensors’ torques (MPET) and flexors’ torques (MPFT) of hip, knee, and ankle joints at each period. MPF, MPET, and MPFT were based on the force-length and force-velocity characteristics of each muscle. All data of one subject were normalized with the time of one cycle, and averaged with all subjects.

RESULTS AND DISCUSSION

The following is the results of 5.1 m/s trials. The results of the other trials were similar to those of 5.1 m/s trials.

Fig. 1 shows measured torques and MPETs of the hip and knee during the support phase for 0% and 9.1% at 5.1 m/s. The peak values and the patterns of the torques of the hip and knee during the support phase were similar between the four grades of slopes. However, as the grade of slope increased, MPET of the hip decreased in the first half of the support phase in which large extensor torque was exerted. Similarly, MPET of the knee during the middle support phase decreased as the grade of slope increased.

Fig. 2 shows MPFs of the gluteus maximus (GM), hamstrings (HM), vastus lateralis (VL), and rectus femoris (RF) during the support phase for 0% and 9.1% at 5.1 m/s. As the grade of slope increased, MPF of GM in the first half of the support phase and that of VL in the middle support phase decreased. MPFs of vastus medialis and vastus intermedius during the middle support phase showed similar pattern to VL, and decreased as the grade of slope increased. On the other hand, few differences were observed in MPFs of HM and RF in the support phase between the four grades of slopes. These results indicate in spite that the patterns and peak values of the joint torques of the hip and knee are similar between the grades of slopes, larger muscular loads of the hip and knee extensors relative to MPET are enhanced in uphill running than level running, and also smaller MPETs of the hip and knee in uphill running are due to smaller MPFs of monoarticular extensors.
Fig. 3 shows joint angular velocities of the hip and knee during the support phase for 0% and 9.1% at 5.1 m/s. Hip extension velocity during the first half of the support phase increased as the grade of slope increased, and showed the reversed patterns to MPET of the hip and MPF of the GM. Moreover, GM shortening velocity during the first half of the support phase increased as the grade of slope increased. Similarly, knee angular velocity during the support phase showed the reverse pattern to MPET of the knee and MPF of the VL. The instant of transition from flexion to extension of the knee and that from eccentric contraction to concentric contraction of the VL were earlier as the grade of slope increased. Higher hip extension velocity and earlier transition from flexion to extension of the knee in uphill running seemed play a role in increasing the mechanical energy of the body (positive work).

These results suggest that the enhanced muscular loads of hip extensors and knee extensors during the support phase in uphill running are due to higher hip extension velocity and earlier transition from flexion to extension of the knee.

Fig. 1 Measured torque and MPET of the hip and knee during the support phase for 0% and 9.1% at 5.1 m/s.

Fig. 2 MPF of GM, HM, VL, and RF during the support phase for 0% and 9.1% at 5.1 m/s.
Fig. 3 Joint angular velocity of the hip and knee during the support phase for 0% and 9.1% at 5.1 m/s.