MECHANICAL ENERGY AND ITS FLOW IN THE SWING LEG FOR ELITE SPRINTERs

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Introduction

Although it is no question that there must be a great generation of joint torque, mechanical energy and power in sprint running, comparison of two joint torque data collected in the maximum sprinting of Carl Lewis in 1984(age 24) and 1991(age 31) indicate that there is no remarkable difference in the maximum torques of the lower limb joints and the torques are not so larger than other sprinters. These facts may suggest that some excellent sprinters can effectively use and transfer the torque, mechanical energy and power generated. As well as in distance running, the effective use of mechanical energy should be emphasized in sprinting more than before. Mechanical energy flow analysis can provide us with information on the effective use of mechanical energy and sprint techniques. Investigating the techniques of elite sprinters during racing, we can obtain more insight into sprint techniques. The purpose of this study was to analyze how elite sprinters flowed mechanical energy in the swing leg during the maximum sprinting of 100m.

Methods

Eight elite sprinters, including Green, the world record holder, and Ito, the Japanese record holder, were videotaped during 55 to 62 m mark of the 100m sprint of The International Super Track and Field Meet in Tokyo in 1999 and 2000, with two high speed VTR cameras for a DLT method. An inverse dynamics approach was applied to compute segmental mechanical energy and joint kinetics of the swing leg. For energy flow analysis, segment torque power (STP) was computed as the inner product of joint torque and segment angular velocity, and joint force power (JFP) as the inner product of joint force and joint velocity.

Results and Discussion

Figure 1 shows mechanical energy for the swing leg of Green, Ito and a student sprinters during official races. I-off and I-on indicate the toeoff and touchdown of the swing leg and C-on is the toeoff of the contralateral leg. Their performance descriptors (velocity, step length and

![Figure 1 Patterns of mechanical energy change of the swing leg for male elite and student sprinters.](image-url)
step frequency) during the videotaping area are 11.19 m/s, 2.46m, 4.55 Hz for Green(100m personal best, 9.79 s), 10.72 m/s, 2.36 m, 4.55 Hz for Ito(10.00 s), and 10.34 m/s, 2.20m, 4.72 Hz for the student sprinter(10.61 s). Although 100m time (10.35 and 10.69 s) of this race for two elite sprinters was not ranked in the top because of a very strong head wind, 2.9 m/s due to a Typhoon, the velocity will be great enough to investigate the sprint techniques and mechanical energy flow. Mechanical energy of the swing leg for the elite sprinters rapidly increased just after the toeoff, reached its maximum about C-on, and then decreased toward I-on through the toeoff of the contralateral leg. Mechanical energy of Green was very large in magnitude and abrupt in change while the magnitude of Ito was smaller and the energy change in the support phase was slower than Green. The magnitude of mechanical energy for the student sprinter was small but there was no big difference in magnitude at I-on. This suggests that high power generation occurring in elite sprinters results in not only high level of mechanical energy but also change in the pattern of mechanical energy during sprinting.

Figures 2 and 3 show schemata of the joint force power and segment torque power of the swing leg for Green and Ito as an index of mechanical energy flow. The straight arrows indicate joint force power and the curved ones indicate segment torque power generated by muscle torque. As a whole, the patterns of JFP and STP were similar in both sprinters. As many investigations described, JFP was much greater (ca. four times) than STP. Large JFP and medium STP in magnitude at the hip joint of the swing leg after I-off indicated that large mechanical energy flow to the swing leg from the trunk occurred during the early swing phase. JFP at the hip for Green was positive at the I-off and attained its maximum (more than 8000W) thereafter. The medium JFP at the hip joint before C-on indicated that the mechanical energy flow from the trunk to the swing leg still continued in this phase. However, at C-on there was no large energy flow by JFP for Green and his JFP changed to the negative in the first half of the contralateral support phase, which indicated mechanical energy flow from the thigh to the trunk. The hip JFP of Ito reached its maximum in the mid point between I-off and C-on and the mechanical energy began to flow from the thigh to the trunk at C-on, which was earlier than that of Green. For both sprinters in the late recovery phase, there was the large and/or medium mechanical energy flow from the foot to the trunk through the shank and thigh by JFP and large flow at the knee by STP. In comparison of these mechanical energy and flow patterns with those of the student sprinter, the differences were observed in both the magnitude and the pattern of JFP at the hip joint rather than STP. The most remarkable was that large and/or medium mechanical energy flows at the hip from the trunk to the thigh by JFP and STP and at the knee by JFP were still observed before and at C-on. These differences may explain his delayed recovery thigh with deeply flexed knee joint before and after the contralateral support phase, which is one of the features of the student sprinter. As JFP is the inner product of joint force and joint velocity, and the velocity of the hip joint is positive (forward), the sigh of the JFP at the hip is determined by the direction of the joint force. The JFP of the hip at C-on for the student sprinter may suggest that the change in the direction of force vector in this stage was too late for the student sprinter.

In general, these results support the findings obtained by the analysis of mechanical energy flow in walking (Winter et al., 1976) and sprint running (Chapman and Caldwell, 1983; Ae et al., 1988; Vardaxis and Hoshizaki, 1989), which mechanical energy was transmitted distally in early recovery phase and proximally in late recovery phase. The results also indicate that the joint force of the hip
has large effects on mechanical energy flow and the motion of the swing leg in sprinting. However, it is worth noting that the timing of the JFP generation in the lower limb joints may determine the pattern of the mechanical energy flow and the leg motion in advanced sprint running.

![Diagram](Green.png)  
Figure 2 JFP and STP of the swing leg at the critical points of the sprinting motion for Green.

![Diagram](Ito.png)  
Figure 3 JFP and STP of the swing leg at the critical points of the sprinting motion for Ito.

**References**


