Kinetic vs Kinematic Analyses for Determining Coordination during Locomotion

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When analyzing the coordination of human motions it is common practice to first examine the motion kinematically and then to look at the causes of the motion, called the kinetics. Kinematic analysis is a fairly straightforward procedure that has become greatly simplified with the latest automated technology provided by such companies as: Ariel Dynamics, Motion Analysis, Northern Digital, Qualysis and Peak Performance, to name a few. These systems are capable of producing reams of numbers defining the patterns of displacement, velocity and acceleration of markers attached to the body and the segments that they can be combined to identify. The difficulty for the researcher is to decide which of this plethora of kinematic histories are the most relevant and discriminatory. A more serious problem, however, is the inclination to use these data to determine how the motion was coordinated by the muscle groups that created the motion.

Newton's Second Law states that for acceleration (a kinematic variable) to occur there must be an associated force present. This concept applies quite understandably to simple bodies, such as, thrown baseballs or blocks sliding on surfaces. Unfortunately, it is more difficult to interpret when applied to complex structures such as the human body. With software provided for the analysis of human motion the body can be reasonably modeled as an interconnected system of rigid bodies. After recording and computing the kinematics of the knee during a sprinting motion, for example, the researcher will be faced with the results that the knee joint flexes during the first part of swing phase and later prior to touch-down is extended. A logical conclusion from these kinematics is that the flexion was caused by the knee flexors performing a concentric contraction and later the extension was due to the knee extensors. Unfortunately, both conclusions would be wrong.

In figure 1, the angular velocity of a sprinter's knee joint is shown, followed by the net moment of force, a kinetic quantity, produced by the structures (mostly muscles) that cross the knee joint. Below these curves is the power produced by the moment of force that is obtained by multiplying the other two variables together. The method used to compute the moment of force is called, inverse dynamics, and is based directly on Newton's Second Law. These data indicate that during the flexion phase of swing the knee extensors acted to reduce the rate of flexion rather than cause the flexion. Furthermore, during the extension phase the knee flexors were the dominant structures performing eccentrically to reduce knee extension and prevent locking of the knee prior to touch-down.

This example dramatically demonstrates the danger of applying kinematic analyses to predict the causes of motions of complex systems of inter-connected segments. Instead one must employ a suitable kinetic analysis (as exemplified by the inverse dynamics approach) to characterize the causes of motion appropriately. Several other examples of applying inverse dynamics and power analyses to various human motions will be presented to support this notion and to demonstrate how the coordination of a locomotor task, such as walking, can be realized.

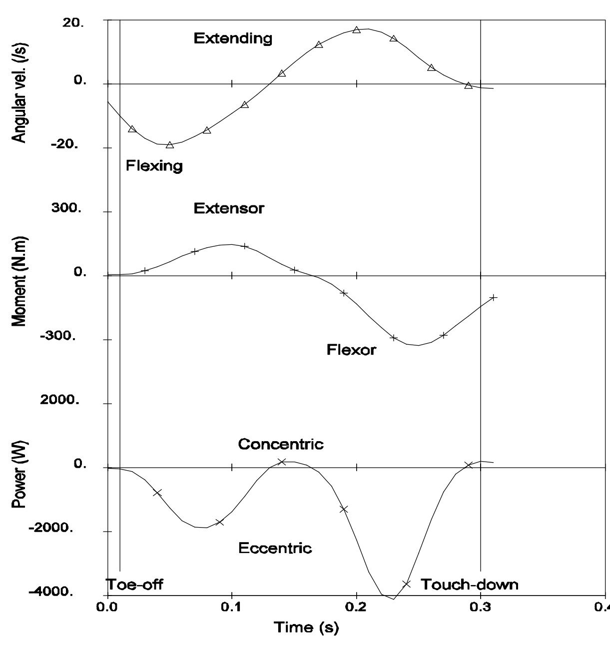

Figure 1 Sprinter's knee angular velocity, moment of force and power during swing.