MUSCLE ENERGY OF TENNIS-STOPS WITH DIFFERENT MOVEMENT PATTERNS

Manfred M. Vieten, Tobias Dietrich, Hartmut Riehle,
University of Konstanz, Germany

KEY WORDS: tennis, muscles, energy, inverse dynamics, stops

INTRODUCTION: Fast runs starting with high accelerations and ending with abrupt stops are fundamental elements of tennis. Stops are performed in various ways. Depending on the surface, footwear and anthropometry, the stopping motion may or may not involve sliding. Stopping without sliding is a motion in which the muscles are shortened or stretched while contracting. During sliding stops, muscles also contract, but almost no shortening or stretching motion is involved. This has a major influence on energy consumption. Muscle energy is a limiting factor in the speed and quality of performance during prolonged matches or tournaments. The purpose of this study is to approximate the relative differences in energy consumption of tennis stops with different stopping patterns.

METHOD: Five male tennis players participated in this study. All played at either the state or national level. Their ages range between 23 and 28 years (24.2±1.9). For each subject, 38 anthropometric measurements were taken. Reflective markers were placed on 17 landmarks (Figure 1). Each participant performed three stops in the university gymnasium (normal floor, with almost no sliding) and three stops on an indoor tennis court on a floor of loose rubber granulate designed to permit sliding. Movements were filmed using three 50 Hz digital cameras with a shutter speed of 1/3500 sec. Digitizing was done using an automatic WinAnalyze system. The resulting marker-coordinates and 38 anthropometric measurements per athlete were the input for the SDS-98 simulation system. SDS-98 created the Hanavan model (Figure 2) and calculated the inverse dynamics in accordance with the filmed movements. No additional external forces were measured. These were calculated from the resulting acceleration of the subject's center of gravity and the constant gravitation. Beside the gravitational force acting on each part of the body, contact forces are exchanged only on the feet when on the ground. Muscle energies were computed for the joints (neck, shoulder, elbow, hip, knee, ankle, spine) using the equation:

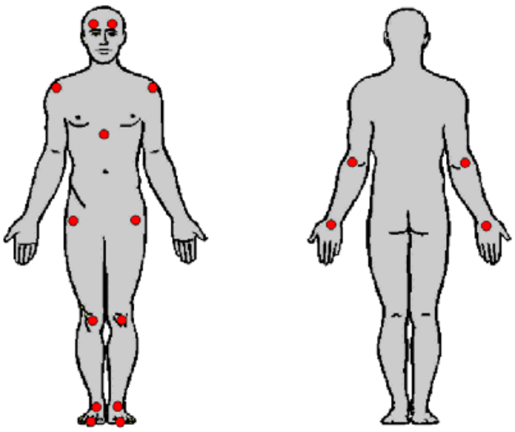

Figure 1

$$E_{mus} = \sum_{i=2}^{15} \int \left| \left\rangle \vec{\omega}_i - \vec{\omega}_{i-1} \right| \vec{T}_i \left\langle \right| dt \,,$$

which is the integral of the absolute value of the scalar product between the relative angular velocity and the torque of the joint. The efficiency η

$$\eta(t) = \frac{E_{mus}(t)}{E_{ini}(t_0) + E_{pot}(t)}$$

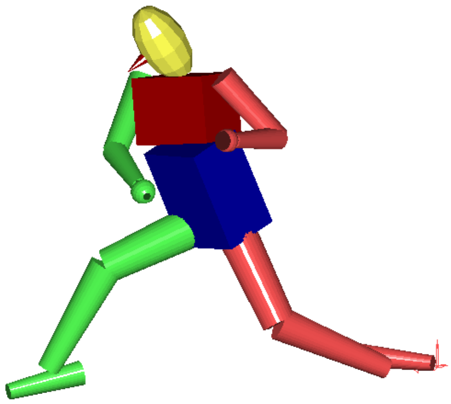

Figure 2

$$E_{ini}(t_0) = E_{tra}(t_0) + E_{rot}(t_0) - E_{pot}(t_0) = \sum_{i=1}^{15} \left(\frac{1}{2} m_i v_i^{\,2} + \tfrac{1}{2} \vec{\omega}_i^{\,t} I_i \vec{\omega}_i - m_i g h_i \right)$$

of a stop was calculated as the quotient of muscle energy divided by the total mechanical energy change from the beginning of the movement to the stop.

RESULTS AND DISCUSSION: Energy efficiency depends on the subject's anthropometry, dynamics, external forces, and the location where the forces are

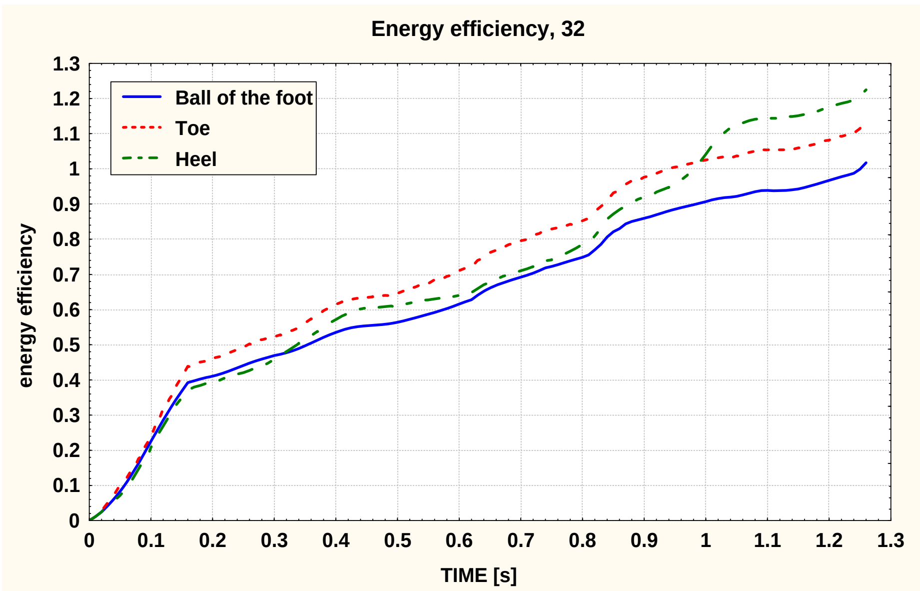

Figure 3

applied. We calculated the influence of changing the location of the center of pressure, for which purpose we chose three different fixed locations for the center of pressure. These were the heel, the toe and the ball of the foot. The results showed similar functional dependency (Figure 3). However, the absolute value of efficiency is influenced by the locations of the center of pressure.

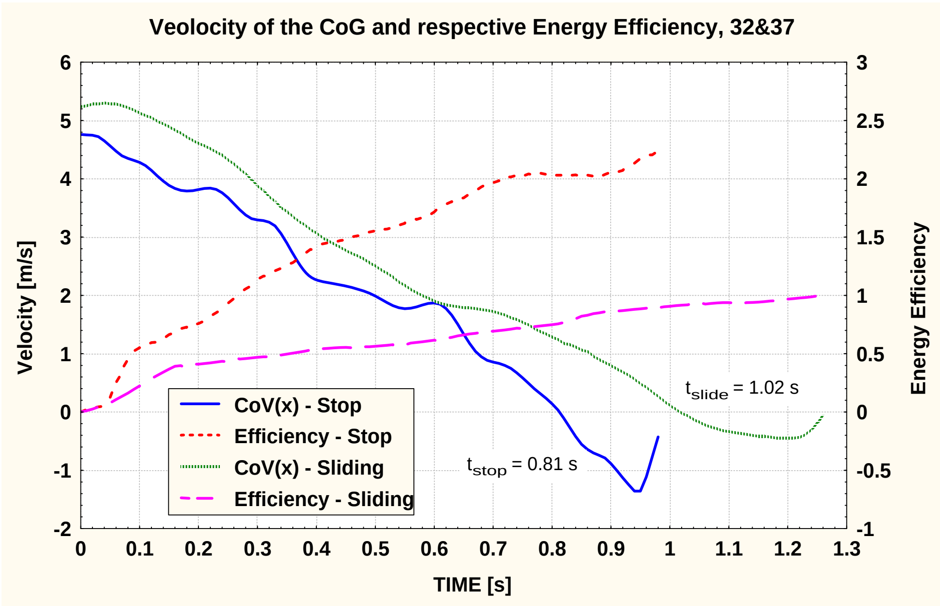

Figure 4

For the actual study, the forces were applied when at least one foot was on the ground. The center of pressure was chosen to be either on the heel or on the ball of the foot depending on the orientation of the foot relative to the ground.

Significant differences in muscle energies (Figure 4) and in dependence on efficiency (Figure 5) were found between stopping motions with and without sliding. Players 2 and 4 also stopped with sliding while running on a normal floor in the gymnasium. This explains the almost identical efficiency on normal floors and on the tennis court. A stopping motion without sliding requires significantly more energy expenditure than a stopping motion with sliding.

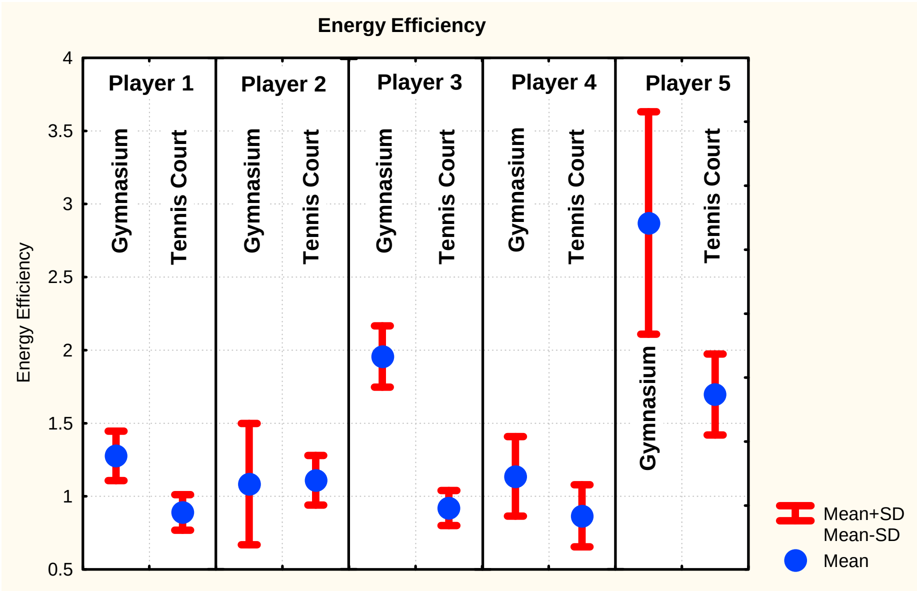

Figure 5

CONCLUSIONS: Deviations may occur between real world data and research calculations. They may be caused by the simplicity of the body model, by digitizing errors, or by uncertainty in calculating the center of pressure of the feet during ground contact. However, the results show quantitatively that sliding stops are favorable for players with low endurance.

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