MECHANICAL ENERGY AND POWER FLOW OF THE UPPER EXTREMITY IN MANUAL WHEELCHAIR PROPULSION

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INTRODUCTION

Complex movements, such as walking, often lead to the calculation of segmental kinematics from which mechanical energies are derived and be used as a tool for the evaluation of locomotion disorders (Olney et al., 1987). Body energy can also be purely calculated from kinematical and kinetic data by the power flow analysis approach. The characteristics of energy generation, absorption and transfer by muscles and energy transfer through the joints could be computed thereafter (Gordon et al., 1980; Winter 1994).

The mechanical efficiency of wheelchair propulsion is very low, only up to 10%. Most studies investigated the mechanical energy and power flow of human walking; the energetic model in analyzing wheelchair propulsion has not been available in the literature. Therefore, we studied the mechanical energy and power flow of upper extremity in manual wheelchair propulsion to understand inefficiency in energy expenditure.

METHOD

Twelve young normal male adults (mean age 23.5 years old) were studied. The ExpertVision™ system (Motion Analysis Corp., Santa Rosa, CA) and an instrumented wheel system were used for three-dimensional kinematics and kinetic analysis of upper extremity in wheelchair propulsion.

RESULTS AND DISCUSSION

The total mechanical energy of an object is the sum of its potential and kinetic energies. The rate at which the mechanical energy level is changing was calculated to determine the mechanical power requirements. For power flow analysis, the power calculated from the vector dot product of the force and the translational velocity, is called passive joint power (Pj). However, the active muscle power (Pm) was calculated from the vector dot product of the joint moment and the body rotational velocity. Power flow (Pf) of each segment were determined by adding the passive power flow at the proximal end and distal end, combined with the active (muscle) power at the proximal end and distal end, and weight power (Ww) (Gordon et al., 1980; Winter 1994). The energy cost per propulsion calculated from the rate of mechanical energy (Em) and power flow (Ep) and their discrepancy (Ed) by Wwb method which allowing transfers of energy between adjacent segments of the same limb, but not between limbs and trunk. Wwb method was proved to be a reliable indication of energy cost during submaximal walking (Unnithan et al., 1999).
upper arm, proximal part of upper extremity, move latest and act as a stabilizer during early propulsion phase.

Figure 1: Mean mechanical energy.

The energy change could be further explained by the power flow analysis. Figure 2 showed the components of power flow of the upper arm during propulsion. During propulsion phase, the increased mechanical energy was mainly from both shoulder muscular power and passive shoulder joint power. The shoulder joint power is produced by the trunk flexor and shoulder muscular power is from the shoulder flexor. Both types of power are combined and transferred to forearm and hand to propel the wheel forward. From the terminal propulsion to middle recovery phase, the joint power flow is transferred upward to trunk from upper arm and forearm to conserve the energy of upper extremity in trunk for next propulsion phase. Mechanical power and power flow of forearm (Figure 3) have similar pattern with less discrepancy. In contrast, greater discrepancy found in upper arm may result from its larger power components but less movement. (Gordon et al., 1980).

The energy cost per propulsion calculated from the rate of mechanical energy ($E_m$) and power flow ($E_p$) and their discrepancy ($E_d$) was 9.4±2.4, 13.7±3.5 and 4.1±2.1 J, respectively. The $E_p$ is significant larger than $E_m$ or $E_d$ (P<0.05). The discrepancy between these two power estimates indicates inefficiency in energy expenditure during wheelchair propulsion. Thus, the power supplied to segments is often greater than the mechanical requirements. And we could use it as an index to individualized guidelines for the configuration of handrim wheelchairs.

Figure 2: Components of mean power flow.

Figure 3: Power flow and mechanical power of forearm.

REFERENCES

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