Energy Recovery During Walking is Decreased in Patients with End-stage Arthritis.

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Disclosures:

Introduction: It is estimated that 49.9 million adults have diagnosed arthritis, and of these individuals 21 million have significant arthritis resulting in activity limitation.(1) It is projected that 67 million adults aged 18 years or older will be diagnosed with arthritis by the year 2030.(2) Ankle, knee and hip osteoarthritis (OA) all lead to activity limitations and progress in a similar manner. Despite broad similarities, important differences exist in etiology and impairment associated with OA in each of these joints. Ankle OA(A-OA) tends to be post-traumatic and affects younger populations. In contrast, hip OA (H-OA) and knee OA (K-OA) are most often degenerative in nature.(3) In comparison to other forms of OA, Glazebrook et al reported that end-stage ankle and hip OA patients report similar outcomes for pain, vitality, emotional stress, social function, and mental health.(4) People affected by K-OA, however, are more likely to report general fatigue and pain during daily activities,(5) walk at reduced speeds(6), and experience muscular fatigue(7) when compared to those without OA. These kinds of impairments to daily life involve both pain and fatigue, but pain has garnered more attention in previous research. Some studies have examined the metabolic costs of gait in people with K-OA, with a focus on cardiac and ventilatory values (outcome measures), without looking at mechanical changes that may influence heart rate and respiration(8, 9). Waters et al.(9) found that patients with unilateral end-stage K-OA have an elevated heart rate during walking that is 153% of the normal rate. These patients also experience a higher oxygen cost per meter traveled. Furthermore, Bernardi et al.(8) found higher VO2 costs and higher pulmonary expiratory ventilation volumes in patients with K-OA. Increased metabolic cost may be explained by increased muscular effort to accelerate and decelerate the center of mass (COM), a factor not previously examined in patients with OA in different joints.

The purpose of this study was to examine mechanical work and energy recovery patterns between patients with end-stage A-OA, K-OA, and hip-OA compared to a group of control subjects in order to test the hypothesis that reduced energy recovery in OA patients increased the metabolic cost of locomotion. Effective energy recovery has been demonstrated in healthy adults who store potential energy (PE) through vertical displacement of the COM and then convert that energy to kinetic energy (KE) that can be used to move the COM forward and upward on a relatively stiff leg. This inverted pendulum pattern can recover up to 70% of the mechanical energy in the system. Limb pathology can interfere with the exchange of KE and PE by changing the amplitude or timing of oscillations in PE and KE. We hypothesized that the hip, knee, and ankle OA patients would have a reduction in energy recovery when compared with a healthy control group and that differences in energy recovery would be worse in A-OA subjects compared with the H-OA and K-OA groups.

Methods: A total of 90 subjects were recruited and tested(30 A-OA, 27 H-OA, 20 K-OA, and 13 Control). End-stage OA was operationally defined as patients who were within 2 weeks of total joint arthroplasty. Control subjects had to be over the age of 45, pain free and have no history of degenerative joint disease. An 8-camera motion analysis system sampling at 120Hz was used in conjunction with four force plates embedded in the walkway sampling at 1200Hz to collect ground reaction forces during level walking. A reflective marker was placed at the sacrum to track the speed of the COM during the 7 self-selected speed walking trials. Oscillations of PE and KE during a stride were calculated from the three force components using MATLAB software (The Mathworks Inc., Natick, Massachusetts, United States) following the computations set forth originally by Cavagna et al.(10) and used in subsequent studies in various populations. The force plate output for a complete stride was converted to acceleration by adjusting for body mass and gravity and then integrated to calculate the velocity of the COM, and then integrated again to calculate the displacement of the COM. These values were used to calculate the KE of the COM in all three planes and the PE of the COM in the vertical plane. Horizontal velocity was determined based on the velocity of the sacral marker. Percentage recovery reflects the conversion of PE into KE and then back into KE again and can be affected by the shape of the energy curves, the difference in amplitude between the oscillation of KE and PE, and the degree to which PE and KE peaks are out of phase.(10) If PE rises as KE falls (energy curves out of phase), energy recovery can be high. The phase relationships can be quantified using percentage congruity,(11) which represents the percent of time throughout the stride in which PE and KE changed in the same direction. Amplitude differences between peak values of KE and PE were also calculated.

A one-way ANOVA was used to examine the differences between groups for walking speed, age, height and weight. The walking speed was statistically different between the groups; therefore, an ANCOVA controlling for walking speed was used to examine differences between the groups when examining energy recovery parameters.

Results: The control subjects walked significantly faster than all of the OA subjects (p<0.0001). The A-OA subjects walked slower than H-OA subjects (p<0.002) with no differences between the K-OA subjects and the other OA groups. Subject velocity
explained 53% of the variance in recovery and when walking at comparable speeds, OA subjects were able to achieve recovery values as high as control subjects. When speed was controlled, the A-OA and H-OA subjects showed significantly (p<0.008) lower recovery values compared to K-OA subjects, indicating that H-OA and A-OA subjects had lower recovery than K-OA. Variation not due to velocity appears to be influenced by congruity (phase), which explained between 80% and 85% of the variation in recovery for all OA groups. Amplitude differences in KE and PE explained no more than 10% of the variation in recovery.

**Discussion:** The results of this study indicate that recovery is most influenced by congruity and walking speed. Patients with end-stage OA of a lower extremity joint demonstrate significantly lower recovery than healthy control subjects due to lower walking speeds and differences in congruity. When compared across OA groups, A-OA and H-OA demonstrated lower recovery and higher congruity values than the K-OA subjects. Congruity in these OA subjects may be altered by an extended period of double-support that delays toe-off and increases the time in which PE and KE are rising together. The lengthening of the double support phase could result from the subject’s inability to push off at the end of the stance phase. For both the H-OA and A-OA subjects this is most likely the result of range of motion limitations in hip extension and ankle plantarflexion, respectively.

**Significance:** This study demonstrates that patients with end-stage OA have reduced energy recovery when compared with healthy control subjects. In addition, this work demonstrates that energy recovery is different based on the joint that is affected by OA and may be influenced by footfall timing and the mechanics of push-off in these subjects.

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**References:**

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