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Joint-specific power absorption during eccentric cycling

Steven J. Elmer [a,*], Matthew L. Madigan [a], Paul C. LaStayo [a,b,c], James C. Martin [a]

[a] Department of Exercise and Sport Science, The University of Utah, Salt Lake City, UT, USA
[b] Department of Physical Therapy, The University of Utah, Salt Lake City, UT, USA
[c] Department of Orthopaedics, The University of Utah, Salt Lake City, UT, USA

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ABSTRACT

Background: Previous investigators have reported that long term eccentric cycling increases muscle size and strength in a variety of populations. The joint-specific strategies used to absorb power during eccentric cycling, however, have not been identified. The purpose of this investigation was to determine the extent to which ankle, knee, and hip joint actions absorb power during eccentric cycling.
Methods: Eight active males resisted the reverse moving pedals of an isokinetic eccentric ergometer (60 rpm) while targeting 20% of their maximum concentric cycling power. Pedal reaction forces and joint kinematics were recorded with an instrumented pedal and instrumented spatial linkage system, respectively. Joint powers were calculated using inverse dynamics; averaged over complete crank revolutions and over extension and flexion phases; and differences were assessed with a one-way ANOVA.
Findings: Ankle, knee, and hip joint actions absorbed 10 (SD 3)%, 58 (SD 8)%, and 29 (SD 9)% of the total power, respectively, with 3 (SD 1)% transferred across the hip. The main power absorbing actions were eccentric knee extension (−139 (SD 21) watts), eccentric hip extension (−51 (SD 31) watts), and eccentric hip flexion (−25 (SD 6) watts).
Interpretation: Eccentric cycling was performed with a combination of knee and hip joint actions which is consistent with submaximal concentric cycling. These data support and extend previous work that eccentric cycling improves knee extensor function and hip extensor muscle cross sectional area. Such information may allow clinicians to take even greater advantage of eccentric cycling as a rehabilitation modality.

1. Introduction

Skeletal muscle can produce greater absolute force during active lengthening (eccentric) than active shortening (concentric) muscle actions (Crenshaw et al., 1995; Westing et al., 1991; Westing and Seger, 1989). Because of this increased capacity for force production, eccentric exercise has been described as a potent stimulus for building muscle mass and improving muscle strength especially in rehabilitation and athletic training settings (LaStayo et al., 2003; Lindstedt et al., 2001; Roig et al., 2009). Further, eccentric exercise can be performed with a lower metabolic cost compared to concentric exercise (Abbott et al., 1952; Bigland-Ritchie and Woods, 1976). This reduced metabolic cost allows an individual to perform repetitive, high-force, multi-joint eccentric muscle actions at a relatively low central hemodynamic and metabolic demand, which may be particularly important in patient populations (Meyer et al., 2003). In a series of investigations, LaStayo (LaStayo et al., 2003, 2009, 2000, 1999) and others (Dibble et al., 2006, 2009; Gerber et al., 2007a,b, 2009; Mueller et al., 2009) demonstrated that 6–12 weeks of eccentric cycle ergometry is an effective method for increasing quadriceps muscle size, knee extensor strength, and mobility in a variety of populations (elderly, total knee arthroplasty patients, patients with Parkinson's disease, and athletes).

While much of the previous research has been focused on knee extensor function, eccentric cycling is a multi-joint, multiple degrees of freedom exercise that can be performed with various joint-specific power absorption strategies. That is, power can be absorbed by ankle, knee, or hip joint actions using a variety of strategies. Gerber et al. (2007a) observed hypertrophy of gluteus maximus muscles in patients who performed eccentric cycling following anterior cruciate ligament reconstruction, which suggests that these individuals also used eccentric hip extension to absorb power. Thus, eccentric cycling may impact hip and possibly ankle function as well as knee extensor function. A thorough understanding of the joint-specific strategies used to induce these muscle growth changes would enhance eccentric exercise prescriptions so that joint and muscle specific impairments could be targeted in rehabilitation.

To our knowledge no previous investigators have reported joint-specific powers during eccentric cycling. During normal concentric cycling, power delivered to the ergometer pedal is

* Corresponding author. Address: Department of Exercise and Sport Science, The University of Utah, 250 S. 1850 E. Room 241, Salt Lake City, UT 84112-0920, USA.
E-mail address: steve.elmer@utah.edu (S.J. Elmer).

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produced through ankle, knee, and hip joint actions and by actions of the upper body that transfer power across the hip (Broker and Gregor, 1994; Ericson, 1988; Martin and Brown, 2009; Reiser et al., 2002). Broker and Gregor (1994) reported that muscular power at the knee and hip accounted for 72% and 9% of the total pedal power, respectively, during submaximal cycling (275 watts, 100 rpm). Ericson (1988) observed that knee extension work was greater than hip extension work when participants cycled at a variety of submaximal workloads across a range of pedaling rates (120–240 watts, 60–100 rpm). In contrast, Martin and Brown (2009) reported that knee extension power was only half as great as hip extension power during maximal cycling. Based on these comparisons, knee extension seems to be the dominate power producing action during submaximal cycling whereas hip extension is the most powerful action during maximal cycling (Broker and Gregor, 1994; Ericson, 1988; Martin and Brown, 2009; Reiser et al., 2002). The extent to which concentric power production strategies relate to eccentric power absorption strategies remains unknown. Thus, the purpose of this investigation was to determine the extent to which ankle, knee, and hip joint actions absorb power during eccentric cycling. We hypothesized that power would be absorbed mostly at the knee with smaller contributions from the ankle and hip because eccentric cycling was performed at submaximal intensities.

2. Methods

Experimental procedures used in this investigation were reviewed and approved by the University of Utah Institutional Review Board. The protocol and procedures were explained verbally and all participants provided written informed consent prior to testing. Eight recreationally active males (age: 24 (SD 1) y; mass: 76 (SD 14) kg; height: 1.8 (SD .06) m who engaged in a variety of different activities (e.g., running, cycling, skiing) participated in this study. Participants performed two practice sessions of eccentric cycling the week prior to the experimental data collection in order to become familiar with the eccentric ergometer and testing protocol. On the experimental day participants reported to the laboratory where body mass, height, thigh length (greater trochanter to lateral femoral condyle), leg length (lateral femoral condyle to lateral malleolus), foot length (distal calcaneous to distal phalanx of great toe), and kinematic foot length (pedal spindle to lateral malleolus) were recorded. Participants performed a concentric cycling warm-up for 5 min at a self-selected intensity and then performed three maximal inertial-load cycling trials in order to determine maximum concentric cycling power (Martin et al., 1997). Eccentric cycling was performed in a recumbent seat position (Fig. 1) that was standardized based on knee joint angle (170°, greater trochanter to lateral femoral condyle to lateral malleolus). Participants were instructed to resist the reverse moving pedals of an isokinetic eccentric ergometer at a specified target power that was 20% of their maximum concentric cycling power. Pedaling rate of the motor driven eccentric ergometer was set to 60 rpm. A Shoberer Rad Masstechnik (SRM) power meter displayed the instantaneous power that the participant was absorbing which allowed participants to resist at the prescribed power. During each trial, participants were given 30 s to stabilize at their target power and then maintained that target power for an additional 30 s during which data were collected.

A Monark (Vansbro, Sweden) cycle ergometer frame and flywheel were used to construct the isokinetic eccentric ergometer.

Fig. 1. Isokinetic eccentric cycle ergometer. Inset images show details of the instrumented force pedal (A) and motor driven flywheel (B). As the pedals move toward the participant (largest gray arrow), the participant resists by applying force to the pedals (black arrow at foot level). Because the magnitude of force produced by the motor exceeds that produced by the participant, the leg extensors (white arrows in thigh) actively lengthen (eccentric muscle action).