BIOMECHANICAL SERVICES AND RESEARCH FOR ATHLETES AND COACHES TO ENAHNCE PERFORMANCE AND PREVENT INJURY

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Athleticism, sport-specific ability, rigorous training supervised by expert coaches and well supported daily training environments are the main determinants of success in international sporting competition (Bosscher et al., 2010). Sport Biomechanists contribute to the training environment largely by identifying and advising on movement technique. This service provides understanding of the mechanical basis of sport-specific performances and injury. However, a kinematic description of technique is often not sufficient to identify improper skill execution. Cycling presents an example where kinematic variability is low, but where underlying force application on the bicycle's pedals and joint-specific powers during pedalling can vary. Such analyses provide a deeper understanding of potential mechanisms underlying injury and athletic performance.

KEY WORDS: cycling, joint-specific power, pedal forces.

INTRODUCTION: Systematic research of elite athletes grows knowledge and expertise, as well as establishing benchmarks for performance models. Participant numbers can be small in elite sport research, but these mean data help identify techniques or kinematic features that characterise typical movement variability and symmetry which can provide insight into injury mechanisms. Biomechanical services to address injury concerns are however most often individualised analyses for a particular athlete. The interpretation of data is based on the practitioner's knowledge, experience and their ability to work and interact with coaches within a service team.

Seated cycling is a coordinated multi-joint task that appears to be highly constrained because of the relatively fixed location of the pelvis on the saddle and the fixed pedal-shoe interface. However, redundant kinematic degrees of freedom are available and permit an infinite number of joint angle combinations that produce the movement patterns of pedalling. Because multiple muscles act across each joint, ankle, knee and hip joint powers can also combine infinitely to produce power at the crank. Despite this potential for varied movement patterns and joint power production, kinematic variability is typically low across pedal revolutions and between limbs providing a convenient experimental model for understanding task construction.

Previous researchers have demonstrated the important role knee joint power plays in producing low to moderate steady-state crank powers (e.g. 250 W, Broker & Gregor, 1994). It is also known that cycling power decreases substantially during maximal cycling trials, but contributions from joint-specific powers to crank power has not been deeply explored when high crank powers are demanded (Martin & Brown, 2009). Joint power contributions as crank power varies are not well known in elite cycling athletes and this knowledge may help develop targeted training programs and injury interventions. Joint-specific powers for a range of cycling conditions including fixed-cadance maximal cycling, pedalling under progressively increasing work rates and during maximal sprinitng will be examined to provide insight into how elite cyclists produce crank power.

METHODS: Cycling bouts between 30 seconds and 40 minutes in duration were examined. First, steady-state cycling was performed by elite male road cyclists on a high inertial load ergometer during a graded step test (100:50:450 Watts). Second, male cyclists performed a maximal 30 second sprint on an isokinetic cycle ergometer (Martin & Brown, 2009). Finally, in a case-study approach, two elite female track sprint cyclists performed high-cadence bouts of sprinting (135 rpm; 145 rpm; maximal cadence) on a high inertial load ergometer. In all testing bouts, pedal forces were recorded from custom-built force pedals and limb kinematics were recorded using a motion capture system or an instrumented spatial linkage (Martin et al., 2007). Ankle, knee and hip joint powers were calculated throughout.

RESULTS: During steady-state cycling, knee joint power was the major contributor to low to moderate crank powers as noted previously (Broker & Gregor, 1994). However, under high crank power demands, hip joint power contributed dramatically more to the total muscular power produced by elite cyclsts comapred to pedalling at low crank powers. During 30 seconds of maximal isokinetic cycling, ankle extension power decreased significantly more (~63%, p=0.010) than knee and hip extension power relative to initial power (Figure 1; Table 1). Relative knee extension power was also significantly less than relative hip extension power during the final three-second interval. These changes in power were accompanied by a decrease in time spent extending by each joint (i.e., decreased duty cycle). Individual cyclists displayed low kinematic variability within cycles and between left and right lower limb movement patterns, but left versus right limb assymmetry was noted in the application of pedal forces.

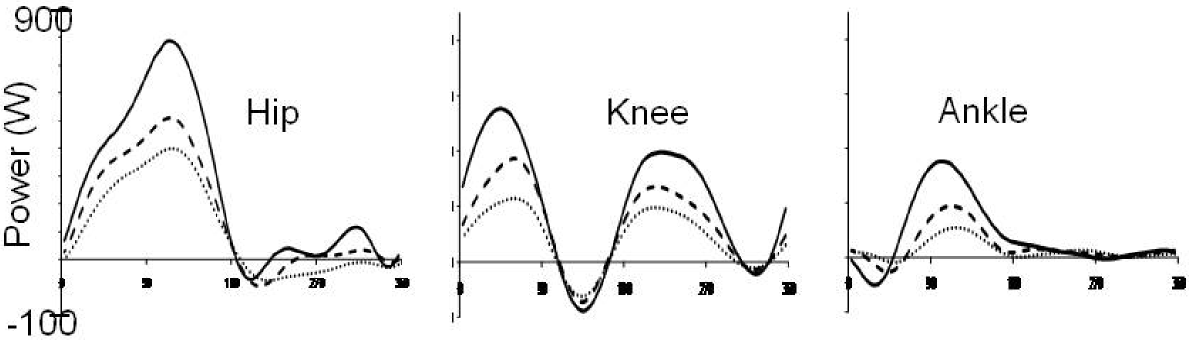

Figure 1: Hip, knee and ankle joint powers for a complete crank cycle during 30 seconds of maximal isokinetic cycling (120 rpm). Peak and mean joint powers decreased as the pedalling bout progressed from the initial 3 seconds (solid line) to the middle 3 seconds (dashed line) to the final and fatgiued 3 seconds (dotted line) of the pedalling bout.

DISCUSSION: Group analyses on elite cyclists have provided a deeper understanding of the neuromuscular construction of the cycling task. From these data, it appears that cycling at high crank powers requires significant increases in the muscular contributions from the proximal hip extensor muscles compared to cycling at moderate to low crank powers. Redistribution of power to proximal muscles to meet task demands has been noted for accelerations from a steady state run (Roberts & Scales, 2002), running up an incline (Roberts & Belliveau, 2005) and for sprint running (Schache et al., 2011). These changes can be associated with changes in work and/or changes in stride frequency and stride length with varying running gaits. Because cycling allows good control of cadence and the length of each pedal stroke remains constant for seated pedalling, the redistribution of power to proximal muscles in cycling appears attributable to an increased work load. The construction of the pedalling task also appears to change with fatigue, with altered duty cycles and greater decrements in ankle joint power compared to knee and hip joint powers after 30 seconds of fatiguing pedalling. The increased ankle fatigue suggests that either peripheral muscle fatigue or changes in motor control strategies are the potential mechanisms for fatigue during maximal cycling trials. The group data have also been useful in case-study approaches to provide biomechanical services for individual athletes. For example, an assessment of a sprint track cyclist that finds relatively low contributions to high crank power from hip extensor muscles may imply a decreased abilty of the athlete to generate hip power and allow interventions to be tailored to improve performance and mitigate injury risks.

Table 1
Mean Total muscular, Ankle, Knee, and Hip joint powers (Watts) during the initial, middle and final 3-second periods of 30 seconds of maximal cycling (Martin & Brown, 2009).

	Total	Ankle	Knee	Hip
Initial	540 ± 31	141 ± 16	217 ± 24	425 ± 32
Mid	344 ± 18	73 ± 12	145 ± 19	295 ± 25
Final	224 ± 13	52 ± 8	89 ± 17	230 ± 16

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