INFLUENCE OF CYCLIST SADDLE SETBACK
ON KNEE JOINT FORCES

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Despite the rapid development of bike fitting services, there is still a lack of scientific evidence on the effects of specific bicycle's parameters on overuse injuries. The aim of this study was to investigate the influence of saddle setback on knee joint forces. Eleven cyclists experimented three saddle setback conditions while pedaling at a steady power output of 200 W and a cadence of 90 rpm. Using a static optimization procedure based on a musculoskeletal model, we estimated knee joint forces. As a first verification step, our preliminary results showed great similarity between muscle activations estimated from the modeling and experimental data (EMG) especially for the knee extensor muscles. Secondly, tibiofemoral joint forces tend to show that a forward sitting position increases tibiofemoral joint shear forces.

KEY WORDS: muscle forces, ergonomics, musculoskeletal modeling.

INTRODUCTION: Bike fitting relates to bike ergonomics and can be defined as the process of setting-up specific bicycle parameters to best suit an individual and optimize his positioning on the bicycle. The ultimate goal is to improve cyclist's performance while preserving his health since an incorrect body position has been linked to an increased risk of overuse injuries. The knee is the most common site for overuse in cyclists (Asplund & St Pierre, 2004) and overuse knee injuries are associated with the repetitive loading of the tibiofemoral and femoropatellar joints inherent with this activity (Ruby, Hull, Kirby, & Jenkins, 1992). Moreover, knee pain has been linked to saddle position but the pathomechanism remains unclear. Bicycle set up affects joint kinematics, resultant moments and muscle activity. More specifically, saddle position has been linked to knee pain (Callaghan, 2005), but the influence of saddle fore-aft position on joint forces remains unclear to date (Bini, Hume, Lanferdini, & Vaz, 2013).

A few studies attempted to investigate joint forces while pedaling with simple geometric models (Bressel, 2001) but a comprehensive musculoskeletal modeling is necessary to accurately estimate joint forces (Delp et al., 2007).

The aim of our study was to develop a musculoskeletal model in order to estimate knee joint forces exhibited during cycling. We also hypothesized that decreasing saddle setback (i.e sitting closer to the handlebars) leads to an increased in knee joint compression and shear forces.

METHODS: Twelve elite cyclists volunteered for the study. A stationary cycle ergometer (SRM, indoor trainer, Schoberer, Germany) was instrumented to conduct the experimentation. A six-component force-torque sensor (Sensix, Poitiers, France) was integrated within each pedal in order to assess the 3D forces exerted by the foot on the pedal. A supplementary sensor was integrated within the seat tube in order to measure the forces applied to the saddle.

Three-dimensional kinematic data were collected at 200Hz (20 cameras, Vicon, Oxford, UK). EMG data were collected using surface electrodes (Delsys, Boston, USA) from the *Gluteus Maximus*, *Gluteus Medius*, *Bicep Femoris*, Vastus Lateralis, *Vastus Medialis*, *Lateral*

Gastrocnemius, *Medial Gastrocnemius*, *Soleus*, *Peroneus Longus*, *Tibialis Anterior*, *Rectus Femoris* and *Semi-Tendinosus*.

Three seating conditions were compared: a *Recommended* position based on individual's anthropometric measurements (de Vey Mestdagh, 1998), together with *Backward* and *Forward* positions for which saddle setback was increased (110%) and decreased (90%) from the *Recommended* (100%) position, respectively (>3cm). Each condition consisted in a 3-min trial at a power output of 200 W and cadence of 90 rpm. Markers data and forces from the 3 force sensors served as input for the computation of muscle forces. A 3D two-legged bicycle-rider musculoskeletal model including 12 segments, 11 joints and 92 actuators, was developed based on the original lower-body model of Delp (1990). The joint forces estimation resulted from the following calculations: 1) Scaling 2) Inverse Kinematics, 3) Static Optimization and 4) Joint Reaction Forces. The model was scaled to match the subject's anthropometry based on experimentally measured markers placed on anatomical landmarks. Muscle lengths and moment arms were estimated from the lower limb kinematics. Main improvements from the classical procedure was the implementation of joint centers' location based on a functional method (Ehrig et al., 2011). Results were averaged among fifteen pedaling cycles. Before the comparison of joint forces between experimental conditions, a qualitative evaluation of muscle activations calculated from the modeling was performed against EMG recordings. EMGs were band-pass filtered then smoothed using a low pass filter (cut off frequency: 20Hz) and normalized to maximal activation obtained during a trial at maximum resistance. To quantify the influence of pedaling sitting position on tibiofemoral loads, the joint reaction forces were computed and expressed in the tibial reference system: Negative force indicates joint compression and positive shear force is directed anteriorly**.**

RESULTS AND DISCUSSION: Results presented here are preliminary and based on one participant only. The magnitude of joint reaction forces is dependent on the muscle activations patterns. As a first verification step, results showed that knee extensor muscles activations resulting from the model displayed better similarity to EMG than knee extensor muscles (Figure 1).

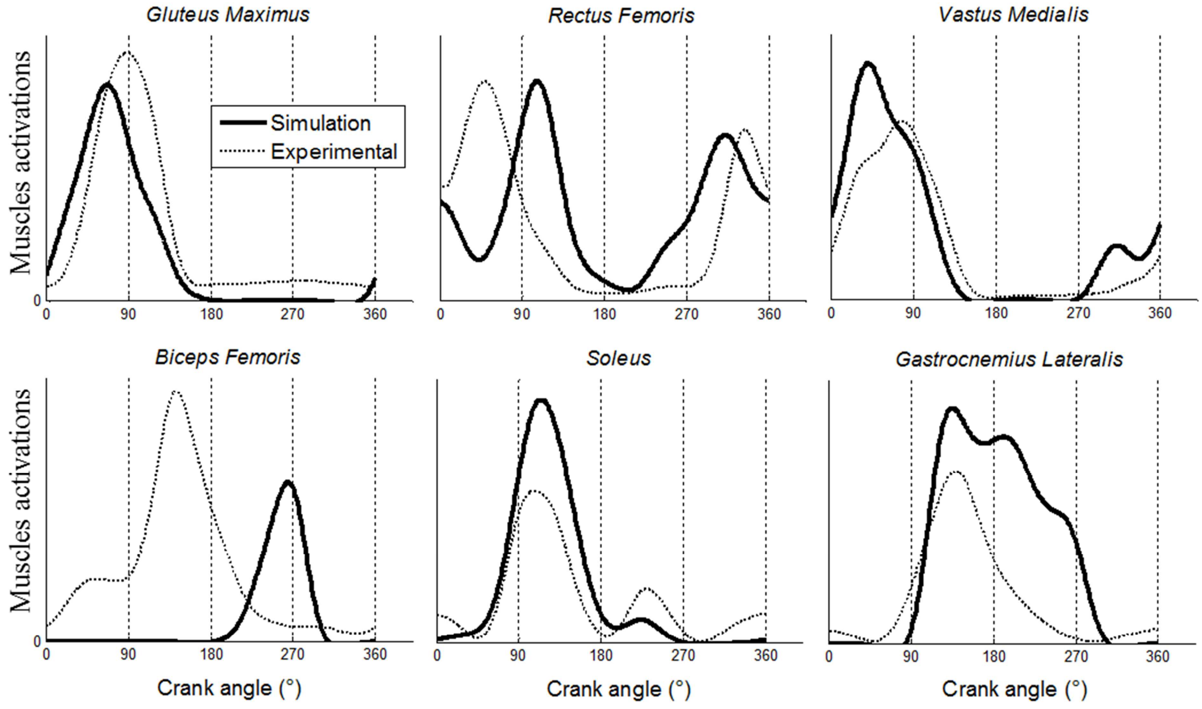

Figure 1 Patterns of muscle activations (solid line) and EMG envelopes (dashed line) during a pedaling cycle (0-360°) in the *Recommended* position. Only 6 muscles illustrated for clarity.

The results of knee joint forces displayed similar patterns to a previous simulation study (Neptune & Kautz, 2000) and in vivo data measured using an instrumented tibial prothesis (Kutzner et al., 2012).

Overall, Forward vs backward conditions have little influence on normal joint forces (Figure 2, left), but during the top transition phase (300-90°), shear forces in the *Forward* condition become especially high, more than twice those encountered during the *Backward* condition. We still need to investigate this phenomenon, but if confirmed for all participants, this may have major implications on the relationship between bike ergonomics and knee overuse injuries. Especially, increased shear forces at the beginning of a downstroke were reported prejudicial for tibial articular cartilage (Wanich, Hodgkins, Columbier, Muraski, & Kennedy, 2007).

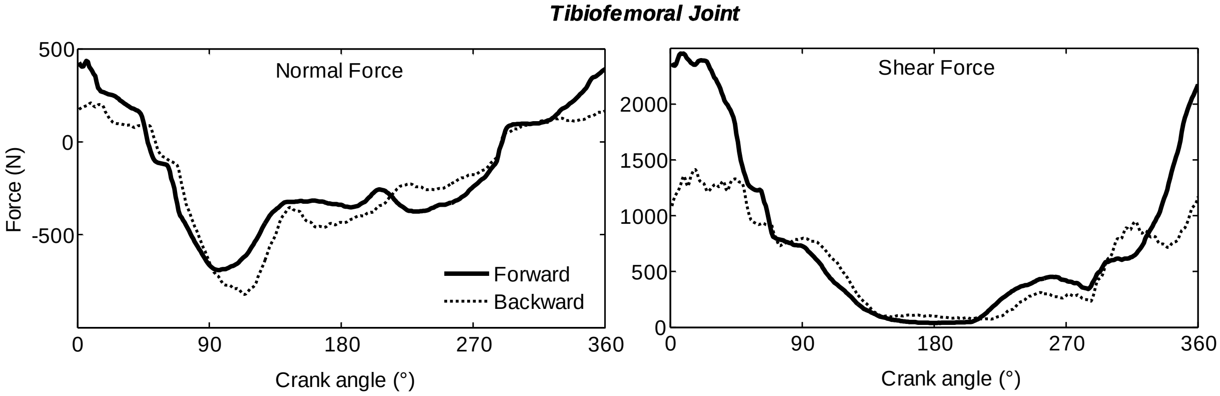

Figure 2 Tibiofemoral joint reaction forces during *Forward* and *Backward* positions. Negative normal force indicates a compressive force, positive shear force is directed anteriorly.

CONCLUSION: These preliminary results tend to demonstrate the capability of the modeling to estimate accurate knee joint forces and discriminate between experimental conditions. The modeling will be refined and applied to all the 12 participants in order to provide reliable recommendations but first results already seems to indicate that sitting forward likely increases knee joint shear forces. Ultimately, this work should benefit to the prevention of knee overuse injuries and also help in the design of rehabilitation protocols.

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