EFFECTS OF SEAT POSITION ON THE JOINT MOMENTS OF THE LOWER EXTREMITIES DURING CYCLING IN THE ELDERLY

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The purpose of this study was to quantify the joint moments of the lower extremities with different seat positions during cycling in elderly. Fifteen older adults performed cycling on a self-developed bicycle ergometer at three horizontal and three vertical seat positions. The pedals were instrumented with six-component load cells to measure pedal reaction forces; and a motion capture system was used to measure body segment kinematic data. Both data sets were used to calculate joint moments during a crank cycle. The results showed that seat positions affected joint moments significantly, especially the horizontal positions. A more posterior seat position led to a more balanced loading at the hip and knee, with less peak muscle loadings. The results will be helpful for cycle design and fitting for the elderly.

KEY WORDS: cyclic sport, fitting parameters, inverse dynamics, aged group

INTRODUCTION: Cycling is widely used for transportation, recreation, sport, and rehabilitation. Cycling is of relatively low-intensity and safe so is suitable for the elderly. However, cycling-related overuse injuries, e.g., knee pain, patellar quadriceps tendinitis, iliotibial band syndrome, can be caused by a combination of inadequate preparation, inappropriate equipment, poor technique and prolonged usage (Wanich, T. et al., 2007). Previous studies have focused mainly on the biomechanical efficiency of road racing in the younger population (Silberman, M. et al., 2005). Few studies have reported the joint loadings in the elderly. The guidelines for bike fitting currently used in young cyclists may not be suitable for the elderly. It is known that geriatric degeneration is accompanied with reduced muscular strength, ability of dynamic balance control and joint coordination (Porter, M. M. et al., 1995). However, guidelines of setting seat positions for elderly cyclists remain unavailable. Knowledge of the joint moments for different seat positions is helpful for injury prevention, improving rehabilitation efficacy and bicycle design for the elderly. Therefore, the current study aimed to quantify the moments at the hip, knee and ankle for different seat positions during cycling in the elderly.

METHODS: Fifteen healthy older adults (age: 77.4 ± 7.7 years, height: 164.9 ± 9.6 cm, mass: 68.7 ± 9.9 kg) participated in the current study with informed written consent as approved by the Institutional Research Board. Each subject wearing 30 skin markers on specific bony landmarks of the pelvis and the lower extremities performed cycling movement on a self-developed ergometer at an average resistance of 20Nm mimicking rehabilitation conditions (Fig. 1). A metronome was used to control the pedalling rate at 35 rpm. Each subject performed cycling at 9 seat positions in random order, each corresponding to a combination of three horizontal and three vertical seat positions. The horizontal positions were those with the distances between crotch of the rider and the axle of the crank equal to 15%, 19% and 24% of the subject's leg length while those for the vertical positions equal to 73%, 77% and 82% of the subject's leg length. The 3D marker trajectories were measured using an 8-camera motion analysis system at a sampling rate of 120Hz (Vicon Motion System Ltd., UK) and the pedal reaction forces were measured by a 6-component load-cell installed in the left pedal. Anatomical reference frames were defined for each lower limb segment following the ISB recommendation. The pedal reaction forces and the marker data were used to calculate the joint moments using inverse dynamics analysis (David A. Winter, 2005). The peak values of the moments of each joint within one cycle were extracted for statistical analysis. A two-way ANOVA was used to test differences between the horizontal and vertical positions. Linear trend detection was performed when a main effect (horizontal, vertical) was found. The significant level was set at 0.05.

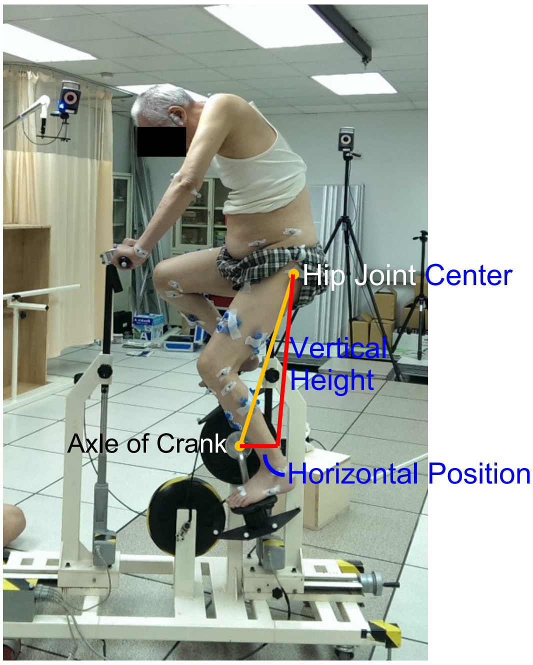

Figure 1: A subject cycling on a house-develop bicycle ergometer that allowed adjustment of horizontal and vertical seat positions. The pedal was also instrumented with a 6-component load cell to measure pedal reaction forces. The vertical and horizontal positions of the seat were defined by tunning the distance between hip joint center of the subject and the axle of the crank.

RESULTS: No interactions between the main factors were found for all variables ($p>0.05$) so only significant main effects are reported here. Horizontal seat positions affected significantly the peak flexor and extensor moments at the hip and knee, as well as peak ankle plantarflexor moments (Fig. 2). With the seat moving posteriorly, the peak extensor moments at the hip were increased linearly (18 to 23.3Nm, $p<0.05$) but the peak flexor moments were decreased linearly (9.6 to 8.3Nm, $p<0.05$). The peak extensor moments at the knee were decreased linearly (26.3 to 22.1Nm, $p<0.05$) but the peak flexor moments were increased linearly (1.2 to 4.3Nm, $p<0.05$). The peak ankle plantarflexor moments were increased linearly (9.9 to 11.0Nm, $p<0.05$). With the seat moving upward, the peak knee flexor moments (0.5 to 6.2Nm, $p<0.05$) and the peak ankle plantarflexor moments (10.2 to 11.0Nm) were all increased linearly.

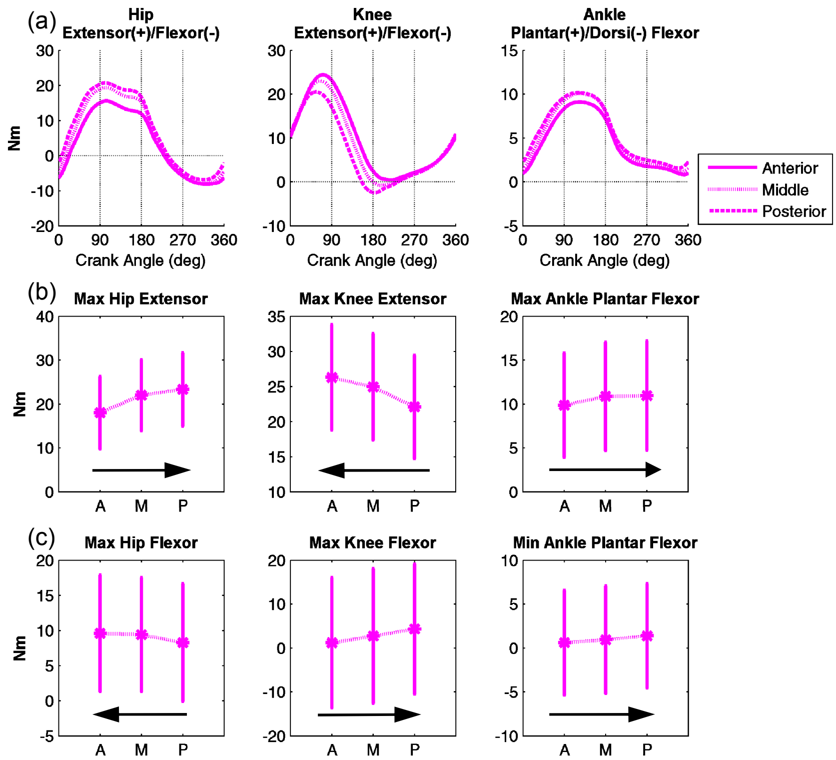

Figure 2: Changes of the joint moments at the hip, knee and ankle with three horizontal seat positions. (a) Averaged joint moment curves in a crank cycle. (b) Peak extensor moments and standard deviations as vertical bars. (c) Peak flexor moments and standard deviations as vertical bars. An arrow was added when a significant linear increasing (right arrow) or decreasing (left arrow) trend was detected.

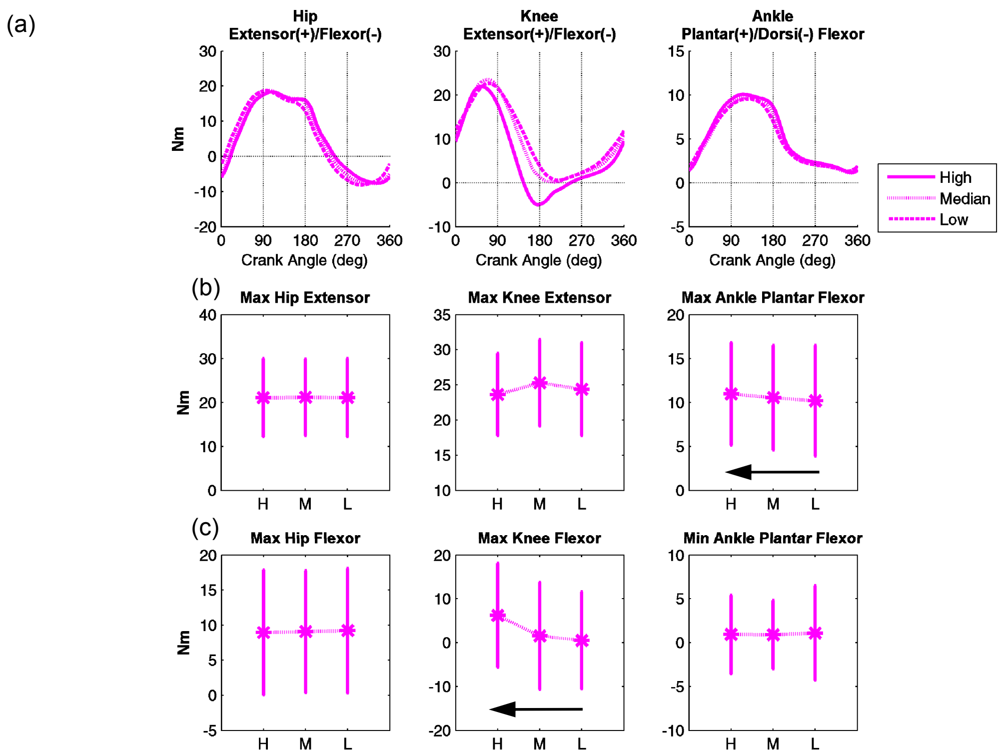

Figure 3: Changes of the joint moments at the hip, knee and ankle with three vertical seat positions. (a) Averaged joint moment curves in a crank cycle. (b) Peak extensor moments and standard deviations as vertical bars. (c) Peak flexor moments and standard deviations as vertical bars. An arrow was added when a significant linear increasing (right arrow) or decreasing (left arrow) trend was detected.

DISCUSSION: Joint loadings in the lower extremities were sensitive to seat positions, especially the horizontal positions. At the middle seat position, the knee extensor moments were generally greater than the hip extensor moments, and the hip flexor moments were greater than the knee flexor moments. When the seat moved anteriorly, the loading of the knee extensors became much greater than those of the hip extensors; the loadings of the hip flexors were also much greater than those of the knee flexors. In other words, the quadriceps was loaded and the hamstrings unloaded at more anterior seat positions, leading to imbalanced loadings between the quadriceps and hamstrings. This would lead to early fatigue of the quadriceps with increased risk of injury. In contrast, when the seat moved posteriorly, loadings of the knee extensors and hip extensors would return to balance, the same was found for the knee flexors and hip flexors. Balanced loadings in the muscles are helpful for longer endurance and thus less fatigue injuries during cycling in the elderly.

CONCLUSION: Seat horizontal positions affect the sharing of the joint loadings in the lower limbs significantly. It is suggested that the elderly choose seat positions at a more posterior position to reduce unbalanced loadings at the joints. The current ergometer and analysis methods can be used to provide user-specific fitting parameters for the elderly cyclists.

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