Kinematical analysis of the Knee During Cycling Exercise Using a 3D Fluoroscopy Method

以三維動態 X 光比對方法進行膝關節於踩踏運動時之運動學分析

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Shih-Wun Hong[1], Tung-Wu Lu[1,2,*], Cheng-Chung Lin[1], Jia-Da Li[1], Yu-Huan Wu[1], Yen-Hung Liu[1], Mei-Ying Kuo[3], Horng-Chaung Hsu[4]

[1] Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan

[2] Department of Orthopaedic Surgery, School of Medicine, National Taiwan University, Taiwan

[3] School of Physical Therapy, China Medical University, Taiwan

[4] Department of Orthopaedics, China Medical University Hospital, Taichung, Taiwan;

Abstract- Knowledge of the kinematics of the knee under different pedaling patterns may help to reduce the risk of overuse injuries and to improve the recovery rate. The current study aimed to measure the 3D skeletal kinematics of the knee during cycling under different pedaling patterns. Eleven healthy young adults performed cycling exercises on an ergometer with the feet placed on the pedals at neutral position, 10 degrees of inversion, and 10 degrees of internal rotation while the skeletal motions of the knee were imaged by a fluoroscopy system. The rotations, translations and articular contact kinematics of the knee were measured using a 3D fluoroscopy method. Significantly decreased contact areas of the knee in both medial and lateral compartments were found in the conditions of inverted or internal rotated foot placement. Decreased contact areas associated with inadequate foot placement may lead to abnormal pressure distributions in the articular surfaces during cycling.

摘要-膝關節於不同踩踏方式之運動學分析有助於預防運動傷害以及增加復健效率。本研究目的在於量測不同踩踏方式下，膝關節之三維運動學。十一位健康成人受試者，於足部正常擺放、內轉十度、以及內翻十度的狀態下，利用三維動態 X 光系統進行踩踏腳踏車動作之擷取，並以三維動態 X 光比對法計算膝關節於踩踏動作下之旋轉、平移、以及接觸面積。結果發現在足部內轉以及內翻的狀態下進行踩踏，膝關節內外側的軟骨接觸面積皆顯著減少，因此不當的踏板擺放可能會導致膝關節內軟骨不正常之壓力分布。

Introduction- Cycling exercises have been used in the rehabilitation of the lower extremities especially in patients with cruciate ligament injuries or reconstruction. Knowledge of the kinematics of the knee under different pedaling patterns may help develop injury-specific cycling exercises to reduce the risk of overuse injuries and to improve the recovery rate. Therefore, the current study aimed to measure the 3D skeletal kinematics of the knee during cycling using a 3D fluoroscopy method under different pedaling patterns.

Methods- Eleven healthy young adults wearing 14 markers on the right lower limb performed cycling exercises on an ergometer with the feet placed on the pedals at neutral position, 10 degrees of inversion, and 10 degrees of internal rotation while the skeletal motions of the knee were imaged by a fluoroscopy system (ALLURA XPER FD, Philips). The knees of the subjects were also CT scanned and used to construct CT-based bone models, which were then registered to the fluoroscopy images using a fluoroscopy-to-CT registration method, giving the rotations, translations and articular contact kinematics of the knee. A one-way analysis of variance was used to analyze the effects of pedaling patterns on each of the variables (α=.05).

Results & Discussion- Accurate 3D skeletal kinematics of the knee during cycling was measured for first time in the literature. Significantly increased knee flexion was found in cycling exercises with the foot internal rotated. Significantly decreased contact areas of the knee in both medial and lateral compartments were found in the conditions of inverted or internal rotated foot placement. Decreased contact areas associated with inadequate foot placement may lead to abnormal pressure distributions in the articular surfaces during cycling, which may be a risk factor of failure of the knee articular cartilage.

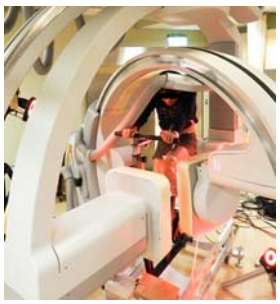

Fig. 1: The instrumented ergonometer integrated with the dynamic fluoroscopy system for cycling exercise

Fig. 2: The bone models obtained from CT scan were registered with fluoroscopic images during pedaling exercise for reproducing the kinematics of the knee.

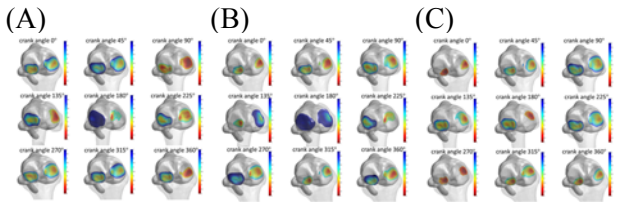

Fig. 3: Contact patterns of a typical subject on the tibia during pedaling exercise when performing under different foot placements. The Foot Neutral (A) was positioned with neutral pedal position; Foot Inversion (B) was positioned with pedal inversion with 10 degrees; and Foot Internal Rotation (C) was positioned with pedal internal rotation with 10 degrees.