GYTS SIMULATION WITH ROBOTIC GAIT TRAINING MODELING AND DYNAMIC ANALYSIS

1, 2Sung-Jae Hwang, 3Young-Kuen Cho, 3Han-Sung Kim, 2Young-Ho Kim and 1John J. Jeka
1Department of Kinesiology and Program in Neuroscience and Cognitive Science, University of Maryland
2Department of Biomedical Engineering and Institute for Medical Engineering, Yonsei University
email: hwangsjungae@gmail.com, web: hwangs.jyonsei.ac.kr

SUMMARY
The gait training simulation which makes it was possible to analyze various biomechanical parameters which are very difficult to measure experimentally during gait training and possible to estimate effects of gait training was also performed by using CAD models of robotic gait training system with human musculoskeletal model and multi-body dynamics. We could analyze changes of joint moments, muscle forces and muscle lengths during RGT and estimate the proper training level of the patient with a gait disorder before starting gait training.

INTRODUCTION
The diagnosis and treatment, especially rehabilitation training of gait disorder is very challenging. A combination of several factors, including muscle spasticity, muscle weakness, bony malacia-ligament, and neurological impairment may contribute to a gait disorder’s abnormality. Theoretically, correcting these factors with the appropriate treatment will improve the gait disorder’s gait pattern. Identifying the set of factors to target with treatment is difficult, however, since the abnormal gait pattern and set of contributing factors differ between patients. Further, the human body can be supposed as a complex 3D linkage, and consequently muscles often have non-intuitive roles during gait that are very difficult to discern from examining electromyography (EMG) and joint moments [1-4]. Recently, some researchers adapted human musculoskeletal models and dynamic analysis to healthy subject and to clinical applications of gait disorders such as stiff knee gait, crouch gait. Their results could provide useful information to establish the direction of treatment or surgery gait disorders through predicting in advance the effect of treatment or surgery by using the human musculoskeletal model and the multi-body dynamic analysis [5-9]. However, the gait training simulation of the gait disorder has never been tried out as far as I know. Gait training simulation of the gait disorder with the human musculoskeletal model can be a very useful method to identify why a specific patient walks with an abnormal gait pattern, and enable us easily to design an appropriate gait training plan.

In this study, we performed the gait training simulation of selected gait disorder to estimate the changes of various biomechanical parameters such as joint moments, changes of muscle length and muscle force adapted to designed gait training pattern by using multi-body dynamic analysis with robotic gait training (RGT) and human musculoskeletal model.

METHODS
We designed 3D modeling of robotic gait training using the commercial CAD software (Adams 2008, MSC.Software, U.S.A.) as shown in Figure 6.2. It was consist of the robotic driving part, the parallelogram and the base treadmill. The robotic driving part was simplified to linear actuators and limb segments. And it was designed to attach to the lower body segment of human musculoskeletal model. Each rotation joint of the robotic driving part was controlled as the hinge joint to allow movements of knee and hip joints only in sagittal plane. The parallelogram was modelled to fix the robotic driving part and to support the upper body segment of human musculoskeletal model. The ground was also designed as the base treadmill with the contact algorithm using the ellipsoid-plane contact method [10].

For human musculoskeletal modeling, we used the commercial CAD software (LifeMOD, LifeModeler, Inc., U.S.A.). The human musculoskeletal model was consist of total 19 segments which were a head, a neck, an upper torso, a lower body segment of human musculoskeletal model. The ground was also designed as the base treadmill with the contact algorithm using the ellipsoid-plane contact method [10].

Figure 1 shows the combination of RGT model and human musculoskeletal model. Bushing joints were adapted between RGT model and human musculoskeletal model at actual fixing positions in developed system.

Figure 1: The combination of designed RGT and human musculoskeletal model
RESULTS AND DISCUSSION

Figure 2 showed the animation of gait training simulation with the developed RGT model and human musculoskeletal model. The input joint angles provided trajectories of segments of RGT model and the input joint moments also controlled rotation velocities of segments of RGT model.

Joint moments of a right hemiplegic patient during gait training simulation were calculated, as shown in Figure 3. Maximum left hip joint extension moment was about 210N·m and flexion moment was almost 0N·m in the initial walk. Maximum right hip joint extension moment was about 180N·m and flexion moment didn’t occur in the initial walk. Maximum left knee joint extension moment was about 90N·m and flexion moment was about 300N·m in the initial walk. Maximum right knee joint extension moment was about 10N·m and flexion moment was about 150N·m in the initial walk.

Muscle forces of major muscles were calculated from multi-body dynamics using the Hill type muscle model of human musculoskeletal model. Figure 4 showed muscle forces and muscle lengths of rectus femoris of a right hemiplegic patient during gait training simulation. Rectus femoris is the biarticular muscle as an agonist for knee extension and hip flexion. Rectus femoris active in the very late stage of swing in preparation for heel contact. Eccentric activation serves to cushion the rate of weight acceptance on the lower extremity and to prevent excessive knee flexion. Rectus femoris show increased activity immediately following toe off to assist hip flexion. We could confirm the muscle force and the muscle length of hemiplegic side were also gradually closed to the normal gait pattern according to increasing training stage.

CONCLUSIONS

The gait training simulation which makes it was possible to analyze various biomechanical parameters which are very difficult to measure experimentally during gait training and possible to estimate effects of gait training was also performed by using CAD models of robotic gait training system with human musculoskeletal model and multi-body dynamics. We could analyze changes of joint moments, muscle forces and muscle lengths during RGT and estimate the proper training level of the patient with a gait disorder before starting gait training.

ACKNOWLEDGEMENTS

This research was financially supported by the Ministry of Knowledge Economy(MKE) and Korea Institute for Advancement of Technology(KIAT) through the Research and Development for Regional Industry. And the funding for this research was also provided by National Institute of Neurological Disorders and Stroke Grants R01 NS-46065 and R01 NS-35070 to J. J. Jeka

REFERENCES