A Study on Estimation of Lower Limb Muscle Forces during Squatting

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Abstract

This study estimated the lower limb muscle forces during two types of squatting by using OpenSim. The results indicete that the muscle forces of the hamstrings, including the biceps femoris muscle, increases as the foot width increases.

A squat is a strength exercise in which a person lowers his hip from a standing position and then stands back up [1]. It is one of the most popular exercises for strengthening the leg and back muscles without using any special equipment. Since incorrect posture during squat exercise causes injury, physical therapists teach patients correct posture during squatting in rehabilitation. The effect is, however, evaluated by follow-up observation. The load on each muscle for each training is not quantitatively evaluated.

Therefore, this study, the lower limb muscle forces during squatting were estimated using the musculoskeletal software OpenSim [2]. Muscle force estimation using OpenSim, which is based on optical motion analysis, is used in various analyses as a non-invasive method. The two types of squat exercises including “normal squat” and “wide squat” were measured during the experiment. A person performs a squat with his legs about shoulder-width apart during “normal squat”, which trains the quadriceps and hamstrings. A person performs a squat with his legs wider than “normal squat” during “wide squat”, which trains the gluteus maximus and gluteus medius muscles. This study estimates the lower limb muscle forces during two types of squatting by using OpenSim and compares the results.

A healthy adult male (height 1.75 m, weight 67 kg) participated in the experiment. The measurement was conducted at National Institute of Technology, Akita College. Following an explanation of the purpose and requirements of the study, the participant gave his written informed consent to participate in the study. Study approval was obtained from the Research Ethics Board, Kogakuin University and National Institute of Technology, Akita College. Fig. 1 shows the sensor positions. The analysis was conducted focusing on the acceleration of a bicycle and the trunk posture. An optical 3D motion analysis device (Bonita10, Vicon) and a floor reaction force plates (Kistler) were used to obtain the kinematic and dynamic data of the lower limbs. The sampling frequency of both systems were 100 Hz. The software OpenSim 3.3 was used to estimate the lower limb muscle forces during squatting. The model used in the analysis was Gait2392, which has 23 degrees of freedom and 92 musculotendon actuators.

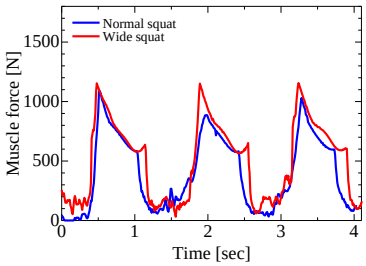

Fig. 1. Muscle force results

Figure 1 shows the result of the biceps femoris long head of the right leg obtained by static optimization calculations. Figure 1 shows the results of three repetitions. The horizontal axis represents the time and the vertical axis represents the estimated muscle force. The waveforms of the results during the two types of squats tended to be similar, indicating that there was no difference in how muscles were used. While the maximum force during wide squats was about 20% higher than normal squats, indicating that widening the stance increases the load on the hamstrings.

References:

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[2] Delp, S. L., Anderson, F. C., Arnold, A. S., Loan, P., Habib, A., John, C. T., Guendelman, E. and Thelen, D. G.: OpenSim: *Open-source software to create and analyze dynamic simulations of movement*, *IEEE Transactions on Biomedical Engineering*, 54(11), 1940-1950, (2007).