EVALUATION OF MECHANICAL PROPERTIES OF KNEE EXTENSOR AND PATELLAR TENDON DURING SQUATTING BY MUSCLE CONTRACTION SENSOR METHOD.

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The purpose of this study was to investigate the mechanical properties of muscle-tendon complex during squatting. Fourteen males were participated in this study. The muscle activities of knee extensor during squatting were measured by surface electromyography. The mechanical property of knee extensor and patellar tendon were measured using a muscle contraction (MC) sensor. Muscle activities of the knee extensor during squatting showed a significant correlation to the MC signal. The mechanical properties of the knee extensor and patellar tendon were closely related to the angle of the knee joint. MC signals of knee extensor showed a consistency on each muscle related to patellar tendon. From these results, it is considered, that the method using an MC sensor is effective for evaluating the changes in dynamic tension in muscle-tendon complex during squatting.

KEY WORDS: MC sensor, squatting, mechanical property, muscle-tendon complex.

INTRODUCTION: It was reported that muscle activity was related to the force output under the isometric and isokinetic conditions (Lawrence & De Luca, 1983). In addition, it is well known that mechanical property by mechnomyography method under the isometric condition significantly changed with increased work loads (Garcia, Vargas, Souza, Imbiriba & Oliveira, 2008). In recent days, the muscle contraction (MC) sensor makes an evaluation of the mechanical property of muscle contraction possible. It was reported that the muscle activities and MC signal were related to the force created on elbow flexion in the isometric contraction (Djordjevic, Tomazic, Narici, Pisot & Meglic, 2014). And, there was a study addressed to the relations between the tension on patellar tendon and knee angle, as well as between the tension on patellar tendon and the torque created on the knee during squatting (Djordjevic, Berdajs, Modic, Gerbec, Stancin, Sodnik & Tomazic, 2014). However, no report is available yet to well explain the relation between the muscle contraction and mechanical property of patellar tendon in dynamic exercise. Also, there is no examination data available to tell the relation between the physiological and mechanical properties of thigh muscle contraction in dynamic exercise. Squatting is one of the most popular exercises for developing strength of the quadriceps muscles, which is also the reason why it is frequently used for rehabilitation and strength training (Djordjevic, Berdajs, Modic, Gerbec, Stancin, Sodnik & Tomazic, 2014). Therefore, the purpose of this study was to evaluate the relation of the muscle activities and mechanical properties of muscle-tendon complex during squatting.

METHODS: Fourteen males (age: 25.1±4.4yrs, height: 174.6±9.6cm, body mass: 72.8±13.4kg, lean body mass: 57.1±12.9kg, %fat: 16.5±6.5%) without disabilities on the knee joint were participated in this study. All the subjects performed a full squatting. Squatting motion was recorded by one high-speed camera. Passive markers were placed on the right side of the acromion, greater trochanter, knee joint and lateral malleolus. Hip and knee joint angles during squatting were calculated by digitizing. In the analyzing process in knee squatting, the Flexion phase covered the motion of the knee from the starting position down to the maximal flexion, whereas the Extension phase covered the motion from the maximal flexion up to the standing position. The muscle activities of knee extensor were measured by surface electromyography. Integrated electrical activities (iEMG) were used as a parameter of muscle activity. As an index of mechanical properties (F_{MC}) the tension of muscle belly for vastus lateralis, rectus femoris, vastus medialis and patellar tendon was measured by the method of MC sensor (TMG-BMC co.). The sensor fitted with a chip was attached to the skin on each applicable muscle and patellar tendon. Then, the tension of the muscle and patellar tendon during the contraction was measured by the sensor in the strain gauge (Fig.1). The length of the tip was the same for all subjects, irrespective of the tissue under the skin, which differed from subject to subject. MC signal during resting and squatting was extracted in all the subjects (Fig.2). We calculated the ratio of maximal signal to the resting. The MC signal during squatting was evaluated by the relative value to the maximal knee flexion (relative F_{MC}) in consideration of the influence of fat.

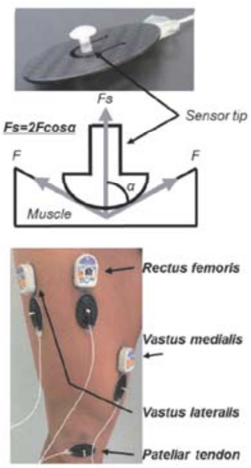

Fig.1. Measurement principle and measurement muscle of the MC sensor.

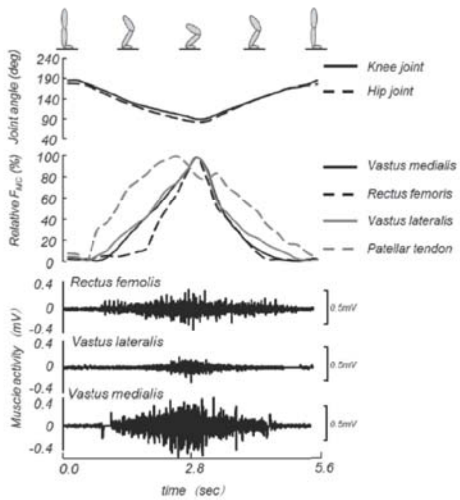

Fig.2. Example of joint angle, relative F_{MC} of knee extensor and EMG during squatting.

RESULTS: The maximal F_{MC} of each muscle was showed in the maximal knee flexion during squatting. On the other hand, the maximal signal of patellar tendon was observed just before the maximal knee flexion was performed. The ratio of maximal signal to the resting of vastus medialis (2.57±0.25) showed significantly higher than the other muscle groups (rectus femoris: 1.67 ± 0.13, vastus latelalis: 1.68 ± 0.15). F_{MC} of each muscle depend on the angle of knee joint in both the flexion and extension phases. Relative F_{MC} of each muscle showed a consistent relation to F_{MC} of patellar tendon in phase of flexion to extension of the knee joint (Fig.3). The relation between relative F_{MC} of patellar tendon and relative F_{MC} of knee extensor showed a similar trend in all the muscle groups (Fig.4). A significant correlation was observed between relative iEMG and relative F_{MC} of knee extensor in both the flexion and extension phases (Fig.5).

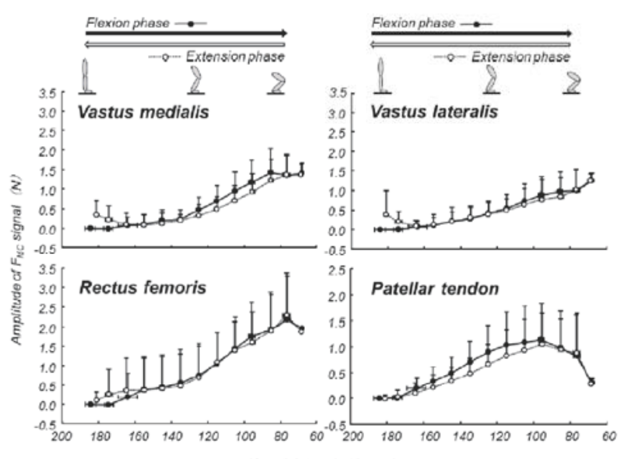

Fig. 3. Relationships between knee joint angle and F_{MC} of knee extensor and patellar tendon during squatting.

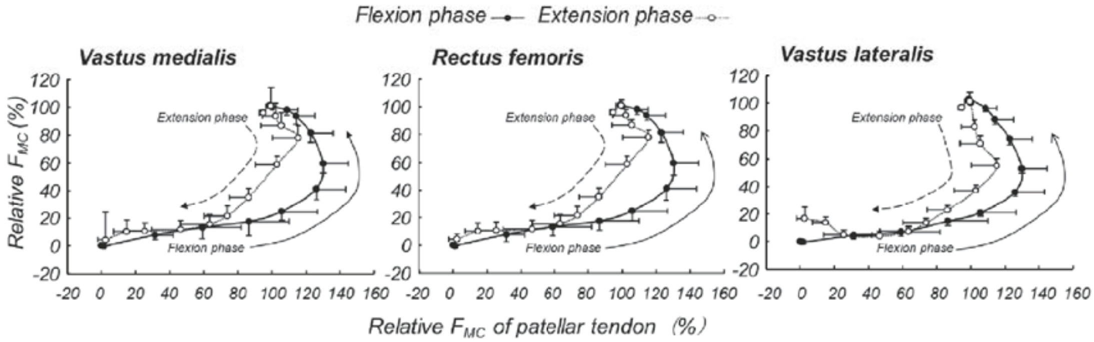

Fig.4. Relationships between relative F_{MC} of patellar and relative F_{MC} of knee extensor during squatting.

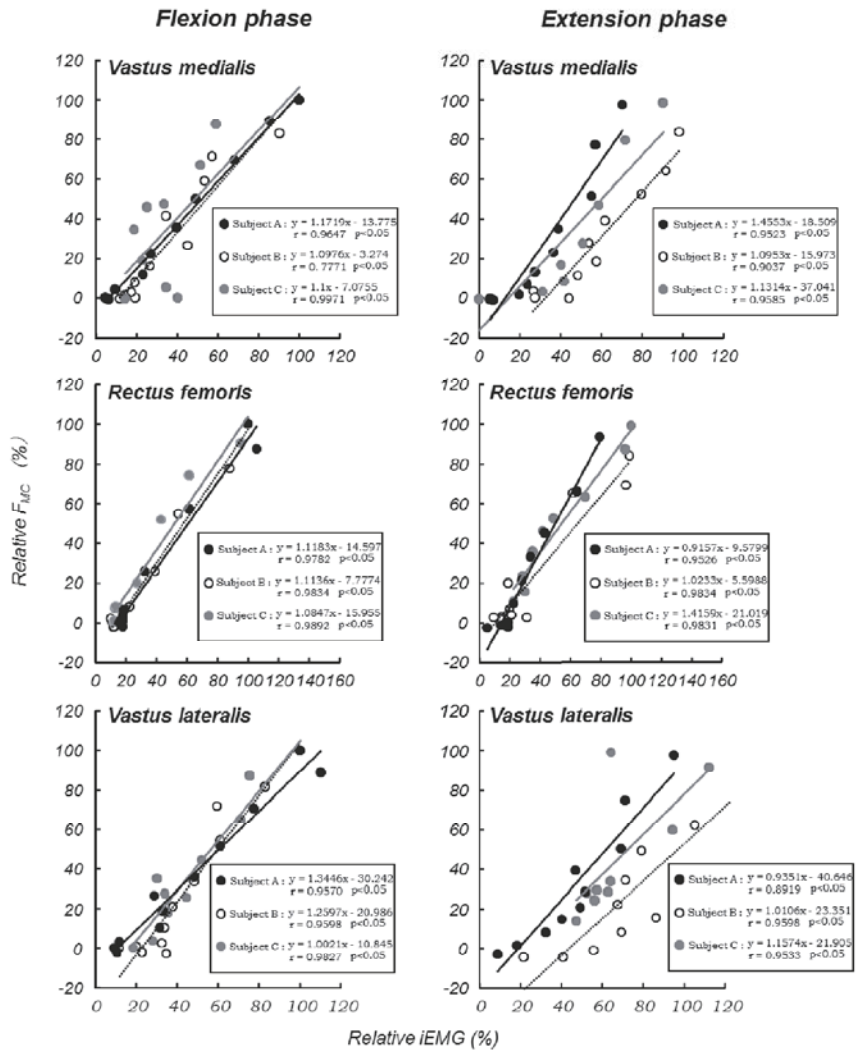

Fig.5. Relationships between relative iEMG and relative F_{MC} of knee extensor.

DISCUSSION: This study was to evaluate the mechanical properties of the knee extensor and patellar tendon during squatting by MC sensor. MC signal was differed in knee extensor and patellar tendon. In the previously study (Djordjevic, Berdajs, Modic, Gerbec, Stancin, Sodnik & Tomazic, 2014), the MC sensor was used in order to understand the mechanical properties of the quadriceps muscle and patellar tendon in half squatting. A linear correlation was observed between the tension of the patellar tendon and the angle of the knee joint, as well as between the tension of the patellar tendon and the knee torque. Further, the relation of muscle force-MC signal was significantly even more linear than the muscle force-iEMG. The relation of the patellar tendon and angle of the knee joint in this study showed as the similar results as the previous research work indicated (Djordjevic, Berdajs, Modic, Gerbec, Stancin, Sodnik & Tomazic, 2014).

This study focused a possible correlation between the F_{MC} of patellar tendon and F_{MC} of knee extensor (vastus medialis, rectus femoris, vastus lateralis). A significant correlation was observed during squatting in the relative iEMG and the relative F_{MC}.

The activities of the knee extensor under the isokinetic condition was differed by the knee joint angle. However, activities of vastus medialis to vastus lateralis ratio does not change. And, the vastus medialis is thought to act as a stabilizer to prevent lateral patella translation (Duffel, Dharni, Strutton & McGregor, 2011). The EMG activation of the rectus femoris as a biarticular muscles is affected by the body adjustments (posture) during squatting (Gheller, Pupo, Lima, Moura & Santos, 2014). MC sensor can be evaluated the mechanical properties of the muscle and tendon in the dynamic exercise. The MC sensor is a wearable biosensor that can measure mechanical property of muscle-tendon complex during contraction (Djordjevic, Stancin, Meglic, Milutinovic, & Tomazic, 2011). To examine the relation between the mechanical properties of muscle and tendon during dynamic exercise is highly recommended to help in athletic training and rehabilitation practices.

CONCLUSION: Mechanical properties of the knee extensor and the patellar tendon was closely related to the muscle length during squatting. And also, a very significant correlation was observed between patellar tendon and mechanical properties of knee extensor. Furthermore, the muscle activities of the knee extensor during squatting showed a significant correlation to the MC signal. Therefore, the mechanical properties and the activities of the muscles were closely related during dynamic exercise. From these results, MC sensor may be a powerful method to evaluate the mechanical changes of muscle-tendon complex in athletic and rehabilitation fields.

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