THE PURPOSE OF THIS STUDY WAS TO INVESTIGATE THE MECHANICAL PROPERTIES OF MUSCLE-TELEON 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 PROPERTIES 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-TELEON COMPLEX DURING SQUATTING.

KEY WORDS: MC SENSOR, SQUATTING, MECHANICAL PROPERTY, MUSCLE-TELEON COMPLEX.


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.](image1)

![Fig.2. Example of joint angle relative $F_{MC}$ of knee extensor and EMG during squating.](image2)

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 lateralis: 1.88 ± 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.](image3)
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 (Djurjevic, Berdalj, Mudic, Gerbec, Stanarj, Sudnik & Turnacic, 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_M of patellar tendon and F_M of knee extensor (vastus medialis, rectus femoris, vastus lateralis). A significant correlation was observed during squatting in the relative iEMG and the relative F_M.

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, Dhami, 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.

REFERENCES: