BACKGROUND MUSCLE ACTIVITY INFLUENCES MECHANICAL RESPONSE DURING REPEATED MAXIMUM MUSCLE CONTRACTIONS

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This study was designed to examine whether background muscle activity and prediction of maximum voluntary contraction (MVC) timing influence the mechanical response elicited by the MVC during passive repetition of shortening, lengthening, and isometric contractions. Background muscle activity and prediction of the timing of MVC influenced the mechanical response elicited by the MVC during passive repetition of shortening, lengthening, and isometric contractions.

KEY WORDS: prediction, maximum voluntary contraction, reaction time.

INTORODUCTION: Physical movement is continuously performed to accomplish a given motor task by the combination of shortening (SHO), lengthening (LEN) and isometric muscle contractions (ISO), while being modified on the basis of afferent information. However, a large force must be exerted in a quite short time if the outcome differs much from what we hoped for. It seems that background muscle activity and prediction of the subsequent movement related to pre-programing and feedforward commands of the central nervous system plays an important role in the ability to generate the force suddenly. A stretch-induced joint torque is modulated by types of the background muscle activity; a stretch after ISO generates larger torque than that after SHO and LEN (Ogiso et al., 2002). Pre-activity induced by predicting the timing of MVC reduces reaction time and compensates for the decline in muscle function due to MVC repetition, although it increases fatigue (Takenaka et al., 2015). Therefore, this study was designed to examine whether background muscle activity and prediction of MVC timing influence the mechanical response elicited by the MVC during passive repetition of SHO, LEN, and ISO.

METHODS: Fifteen men (age 19.9 ± 1.2 years, height 170.8 ± 4.3 cm, weight 64.1 ± 5.1 kg) participated in this study. All subjects were in good health, with no orthopedic or neuromuscular abnormalities. Subjects were fully informed of the nature and possible consequences of the study before providing written informed consent. Experiments were approved by the Ethics Committee of Kogakkan University and conducted in accordance with the Declaration of Helsinki. After a warm-up, subjects were placed in a comfortable, upright seated position on an isokinetic dynamometer chair, with the dynamometer fulcrum aligned with the extension-flexion axis of the left knee joint. Subjects were secured using shin, thigh, pelvic, and torso stabilization straps to minimize extraneous body movements and were asked to fold their arms across their chest during the experiment. The knee movement range of motion was from 0° extension to 90° flexion and was tested at 90°/s (0° = straight leg). They performed 100 consecutive isokinetic knee extension-flexion movements passively, 50 of which were performed at MVC. To cue subjects to perform extension-flexion movements at MVC, a photo beam unit consisting of light-emitting and light-receiving devices was set up on either side of the left shank such that an LED placed in front of the subject could be switched on as a prompt when the shin moved through the beam at a 60° knee joint angle. Immediately before the knee joint angle reached 60°, the angular velocity reached a constant velocity of 90°/s. MVC was repeated during passive SHO or LEN in every second trial (50 total, C1 trials) or at random intervals (C2 trials). Subjects were informed of the light cue timing beforehand in the C1 trials only. MVC was also repeated 50 times during ISO with a 60° knee angle every 4 s in the C1 trials, and at random five times per 20 s in the C2 trials. After the experiment, subjects graded the force and timing of MVC performance on a scale of 1 to 5 (1 = very poor; 2 = poor; 3 = average; 4 = good; 5 = very good) and the degree of fatigue on a scale of 1 to 5 (1 = not tired; 2 = a little tired; 3 = fairly tired; 4 = tired; 5 = very tired) for repetitions 1−10, 11–20, 21−30, 31–40, and 41−50. The knee extension torque exerted at MVC (MVC torque) was measured along with data on the knee joint angle (KJA) and timing of the light cue. Gradients and correlation coefficients were calculated by executing single regression analysis for all data with time as the x-axis and torque as the y-axis. Calculations were performed before (P1) and after (P2) the sharp increase subsequent to the MVC light cue, and after the values stopped increasing but while they still remained high (P3). The differences between the intersection points of the P1 and P2 regression lines and the P2 and P3 regression lines were defined as increases in MVC torque (ΔMVC). The gradients were defined as the velocities of ΔMVC. Reaction times of ΔMVC were defined as the time at the intersection point of the P1 and P2 regression lines. These data were measured during the fourth, fifth, and sixth repetitions of each 10-repetition set (1−10, 11–20, 21−30, 31–40, and 41−50) and averaged.

RESULTS: In SHO and LEN, reaction times and ΔMVC were significantly shorter and greater, respectively, in C1 than in C2 ($p < 0.01$). On the other hand, there were no such differences between C1 and C2 in ISO (Figure 1). In C1, reaction times significantly decreased with the number of MVC repetitions in every contraction ($p < 0.01$). ΔMVC was largest in LEN and smallest in SHO throughout the MVC repetitions. Of all contraction types, LEN showed the largest difference in ΔMVC between C1 and C2 (Figure 2). Degree of fatigue increased significantly with the number of MVC repetitions, whereas ΔMVC increased significantly up to the 30th repetition in ISO, the 40th repetition in LEN, and the last repetition in SHO. Self-evaluation of the force and timing of MVC performance remained unchanged irrespective of the number of MVC repetitions; however, self-evaluation of timing was significantly different between C1 and C2 in SHO and LEN.

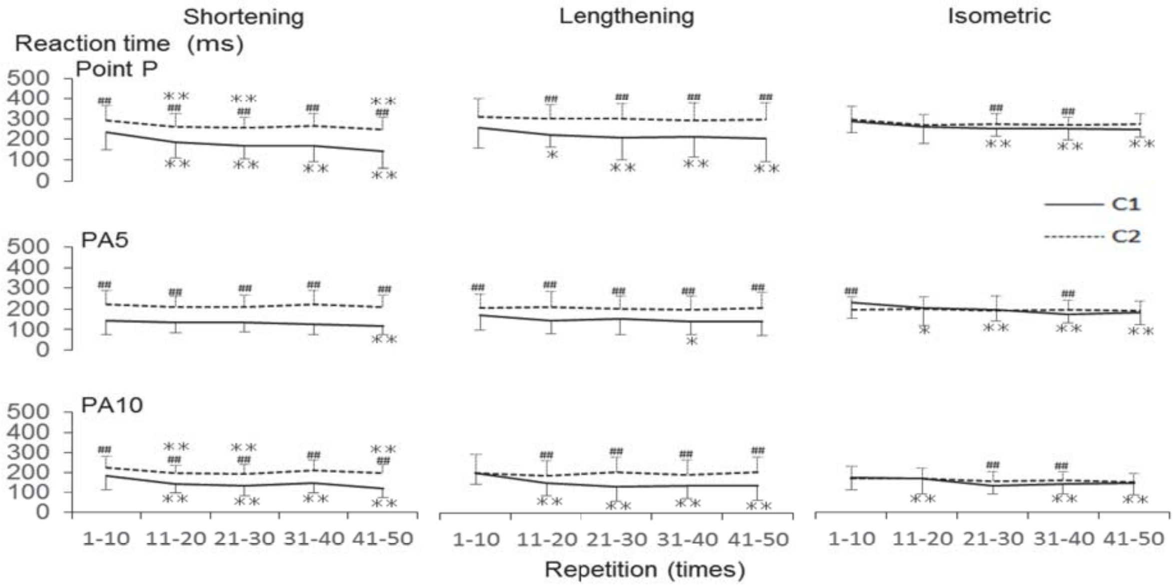

Figure 1: Reaction time. Significant differences from value at 1st to 10th repetition: * p＜0.05 ; ** p＜0.01. Significant differences between C1 and C2: # p＜0.05 ; ## p＜0.01.

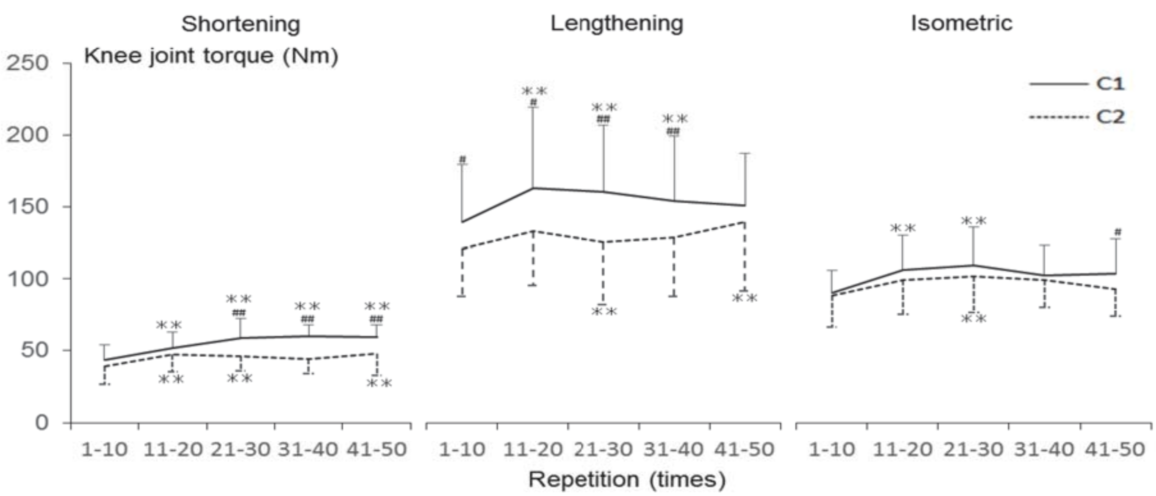

Figure 2: Increases in MVC torque. Significant differences from value at 1st to 10th repetition: * p＜0.05 ; ** p＜0.01. Significant differences between C1 and C2: # p＜0.05 ; ## p＜0.01.

DISCUSSION: Predicting subsequent movement plays an important role in improving movement performance and preventing injuries. Prediction excites the alpha motoneurons and leads to pre-activity (Kasai, 1982), which increases the stretch-reflex mechanical response (Ogiso et al., 2002) and decreases latency (Kasai, 1980). When subjects were informed beforehand of the MVC light cue in the present study, ΔMVC increased and reaction time decreased when MVC was performed in SHO and LEN, but not in ISO. Considering that the self-evaluated force and timing of MVC performance were not significantly different between the three contraction types, these findings suggest that ISO is a better condition for performing MVC compared with the phasic contractions. LEN generated the greatest ΔMVC of the three contraction types. Earlier studies suggested that the larger force exerted by lengthening contraction is closely related to the number of cross-bridges and the viscoelasticity of the connective tissues (Saito et al., 2003). Larger ΔMVC during lengthening may also be generated via similar mechanisms. However, the large ΔMVC between C1 and C2 in LEN may indicate the difficulty of performing MVC in the opposite direction while a muscle is lengthening. Predicting the timing of force exertion, therefore, is more important during lengthening than during other contractions. The degree of subject-reported fatigue increased with the number of MVC repetitions. Though fatigue generally decreases MVC force, ΔMVC increased or was maintained in every contraction type during MVC repetition. This may be a factor of the present protocol, in which 1) MVC was either repeated in alternate repetitions of 100 consecutive isokinetic knee extension-flexion movements, or was randomly interspersed, and 2) MVC was exerted at extremely short duration.

CONCLUSION: Background muscle activity and prediction of the timing of MVC influenced the mechanical response elicited by the MVC during passive repetition of SHO, LEN, and ISO. ΔMVC was greatest during LEN and smallest during SHO. Informing subjects beforehand of the MVC timing increased ΔMVC and decreased reaction time when MVC was performed during SHO or LEN. This subject foreknowledge had a strong effect on ΔMVC during LEN, indicating that MVC is difficult to perform during this type of contraction. On the other hand, subject foreknowledge had little effect on ΔMVC during ISO, suggesting that this contraction is better than phasic contractions for performing MVC.

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