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Interrelationship between Quadriceps' Activation and Inhibition as a Function of Knee-Joint Angle and Muscle Length: A Torque and Electro and Mechanomyographic Investigation

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Abstract : Incomplete activation, or activation failure, of motor units during maximal voluntary contractions is often referred to as muscle inhibition (MI), and is defined as the inability of the central nervous system to maximally drive a muscle during a voluntary contraction. The purpose of the present study was to assess the interrelationship amongst peak torque (PT), muscle inhibition (MI; incomplete activation of motor units), and voluntary muscle activation (VMA) of the quadriceps' muscle group as a function of knee angle and muscle length during maximal voluntary isometric contractions (MVICs). Nine young adult males (mean + standard deviation: age: 21.58 + 1.30 years; height: 180.07 + 4.99 cm; weight: 89.07 + 7.55 kg) performed MVICs in random order with the knee at 15, 55, and 95° flexion. MI was assessed using the interpolated twitch technique and was estimated by the amount of additional knee extensor PT evoked by the superimposed twitch during MVICs. Voluntary muscle activation was estimated by root mean square amplitude electromyography (EMGrms) and mechanomyography (MMGrms) of agonist (vastus medialis [VM], vastus lateralis [VL], and rectus femoris [RF]) and antagonist (biceps femoris ([BF]) muscles during MVICs. Data were analyzed using separate repeated measures analysis of variance. Results revealed a strong dependency of quadriceps' PT ($p < 0.001$), MI ($p < 0.001$) and MA ($p < 0.01$) on knee joint position: PT was smallest at the most shortened muscle position (15°) and greatest at mid-position (55°); MI and MA were smallest at the most shortened muscle position (15°) and greatest at the most lengthened position (95°), with the RF showing the greatest change in MA. It is hypothesized that the ability to more fully activate the quadriceps at short compared to longer muscle lengths (96% contracted at 15°; 91% at 55°; 90% at 95°) might partly compensate for the unfavorable force-length mechanics at the more extended position and consequent declines in VMA (decreases in EMGrms and MMGrms muscle amplitude during MVICs) and force production (PT = 111-Nm at 15°, 217-NM at 55°, 199-Nm at 95°). Biceps femoris EMG and MMG data showed no statistical differences ($p = 0.11$ and 0.12, respectively) at joint angles tested, although there were greater values at the extended position. Increased BF muscle amplitude at this position could be a mechanism by which anterior shear and tibial rotation induced by high quadriceps' activity are countered. Measuring and understanding the degree to which one sees MI and VMA in the QF muscle has particular clinical relevance because different knee-joint disorders, such ligament injuries or osteoarthritis, increase levels of MI observed and markedly reduced the capability of full VMA.

Keywords : electromyography, interpolated twitch technique, mechanomyography, muscle activation, muscle inhibition
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