MUSCLE MECHANICS FOR EXERCISE PERFORMANCE ENHANCEMENT

Yasuo Kawakami

Faculty of Sport Sciences, Waseda University, Saitama, Japan

Some examples are introduced to enhance exercise performance (from a single joint movement to running and jumping). There actually are numerous factors affecting exercise performance in but not limited to biomechanical, physiological, medical, and engineering aspects. In this session, I will focus on muscle mechanics that can be “manipulated” with some devices executable by a practitioner or with the use of artificial apparatuses.

KEY WORDS: muscle physiology and mechanics, muscle-tendon unit, supporting devices.

INTRODUCTION: Human movements are comprised of various joint motions. Joint torque and power are generated through contractions of skeletal muscles. Individual joint performance is thus greatly affected by the force- and power-generating properties of skeletal muscles, which are influenced by contractile status of muscle fibers within. There are various factors affecting force/power generation of muscle fibers, apart from their inherent physiological properties such as the force-length relationships. In this session I will point out some examples of such ‘extra’ factors that can be manipulated in such a way to lead enhancement of exercise performance.

FACTOR 1–POST-ACTIVATION POTENTIATION: It has been known that the joint torque generated by a twitch contraction is increased after a brief muscle contraction (post-activation twitch potentiation) (Miyamoto, Yanai & Kawakami, 2011). Recently, it was demonstrated that a brief contraction also enhanced subsequent dynamic joint torque and power with the maximal voluntary effort. We have shown that the maximal voluntary isometric contraction can increase subsequent isokinetic concentric torque with the maximal voluntary effort (Miyamoto, Kanehisa, Kawakami, 2012) and that the squat exercise results in improvement of subsequent maximal jump performance (Fukutani, Kawakami et al., 2014). Such evidence clearly indicates that a brief, intensive muscle contraction can enhance the following brief, intensive exercise performance. However, such a potentiation effect does not occur immediately after the initial contraction but after a certain period (approximately 1 to 3 min) following the MVC (Miyamoto, Kanehisa, Kawakami 2012), due to the trade-off between potentiation and fatigue that occur during the initial contraction (Sale, 2002). We have recently shown that after 12-wk resistance training, the maximal voluntary concentric torque was potentiated (104%) also immediately after the maximal contraction and was further increased after 1min (108%) and 3min (107%) (Miyamoto, Kawakami et al., 2013). This finding indicates that the contraction-induced potentiation of maximal voluntary dynamic performance can be strengthened by training.

FACTOR 2–MUSCLE-TENDON INTERACTION: In a skeletal muscle, muscle fibers are packed in bundles (fascicles) extending in many cases from proximal to distal tendinous tissues (tendons and aponeuroses). A skeletal muscle therefore should be regarded as a muscle-tendon unit (MTU) (Kawakami, 2012). The arrangement of fascicles and tendinous tissues (muscle architecture) is a major determinant of the capacity of a skeletal muscle as an actuator, and its impact can be greater than that of physiological properties of the muscle such as fiber types (Burkholder et al., 1994). The tendinous tissues possess elastic properties (Alexander & Bennet-Clark, 1977). Fascicles as actuators within MTU stretch the tendinous tissues as springs during contraction (Kawakami & Fukunaga, 2006). Fukunaga, Kawakami et al. (2001) showed an interaction between fascicles and tendinous tissues during walking, concluding that the tendinous tissues play a major role as a spring during locomotory movements. Kawakami et al. (2002) showed that the fascicle behavior (changes in both lengths and activation levels) of the gastrocnemius MTU during a maximal ankle hopping exercise was different when performed with and without a counter-movement. Estimated muscle power during the shortening phase of MTU was greater in the former compared to the latter. This study clearly shows that with a counter-movement, MTU works in such a way that fascicles are responsible for force and tendinous tissues for speed (Kawakami & Fukunaga, 2006). Hirayama, Kawakami et al. (2012) further demonstrated that one learns through practice to effectively use the muscle-tendon interaction in such a way that fascicles being lengthened less, allowing the tendinous tissues to act more like a spring for greater work generation, by modulating activation strategy of muscle fibers. Collectively, one can enhance exercise performance by optimizing the muscle-tendon interaction through practice, without significantly altering force/power-producing capacity of the muscle fibers.

FACTOR 3–ARTIFICIAL SUPPORT FOR MOVEMENT PERFORMANCE: In recent years, the use of elastic compression garments such as tights and stockings has become widespread in sports scenes. Studies have provided some evidence regarding efficacy of wearing compression garments on exercise performance (e.g. Bringard et al.

2006), no consensus has been reached as to whether or not the use of compression stockings can have positive effects on physiological responses during exercise (MacRae et al. 2011). We have shown that the compression short-tight with an adequate pressure intensity can reduce fatigue of the thigh muscles developed over submaximal running exercise (Miyamoto & Kawakami, 2014). We have further shown that under an adequate pressure on the thigh, electrically-evoked knee extension torque is increased but not under pressures other than optimal (Matsumoto, Kawakami et al., 2013), which can be one of the reasons for the possible exercise performance improvement with compression garments. Miyamoto & Kawakami (2015) showed a decrease of the development of muscle fatigue over submaximal running exercise with compression stockings without graduated pressure profile that has been conventionally adopted in medical applications. These findings suggest that the reduction of peripheral venous pooling and facilitated venous return, which most studies ascribe for the reduction of fatigue by the compression garments (Liu et al., 2008), are not really true and that there is a possibility of the efficacy of compression modality on the brief, intensive exercise performance.

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