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Facilitation of Quadriceps Activation Following a Concentric Knee Flexion During Reciprocal Knee Movement: The Influence of Muscle Preloading

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국문요약

교차적 슬관절 굴곡-신전 시 슬관절 굴곡근의 구심성 수축에 의한 선행부하가 대퇴사두근의 활성화에 미치는 영향

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본 연구는 슬관전 신전 직전에 수행된 선행 슬관절 굴곡이 슬관절 신전근의 최대 근력발생 및 근육 활성도(activation)에 미치는 영향을 알아보기 위하여 실시되었다. 16명의 정상인이 Cybex II 등속운동기구에서 3가지 다른 운동 속도(100°/s, 200°/s, 300°/s)와 2가지 다른 근육 활성 조건(선행부하가 없는 조건과 선행부하 조건)에서 슬관절의 최대 신전을 수행하였다. 연구대상자들에게 선행부하 없는 조건에서는 90° 슬관절 굴곡 상태에서0º 까지 최대 신전을 수행하도록 하였고, 선행부하 조건에서는 구심성 슬와부 근육의 구심성 수축으로 0°에서 110°까지 굴곡한 후, 다시 0°까지 최대 신전을 하도록 요구하였다. 종속변인으로는 내측광근과 외측광근의 최대 근전도와 최대 신전근력을 측정하였다. 실험 결과 최대 근전도와 최대 근력 모두 선행부하 조건에서 높게 나타났으며, 운동 속도가 증가함에 따라 최대 근력은 감소하는 전형적인 최대 근력-운동속도 상관법칙이 본 실험에서도 나타났다. 또한 운동속도와 전환속도 간의 간섭이 없는 것으로 나타나, 슬관절 신전근에 선행부하(preloading)를 가하는 것이 최대 근력-운동속도 상관법칙(force-velocity relation)에 영향을 미치지 못하는 것으로 해석되었다. 선행부하로 인해 증가된 최대 근력 및 근 활성도의 증가는 주로 신경촉진에 의한 것으로 해석된다.

핵심단어: 대퇴사두근 신전; 선행부하; 최대 근력-운동속도 상관법칙.

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Introduction

The maximal concentric muscular force and the resultant joint torque that and individual can exert can be increased by muscle preloading (Asmussen, 1974; Bosco et al, 1982; Caiozzo et al, 1989; Roy et al, 1990; Svantesson et al, 1994; Svantesson et al, 1991). A factor that may involve an interaction between neural and mechanical mechanisms is the degree and timing of muscle preloading. Muscle preloading involves stretching the muscle prior to concentric activation of that muscle. There is considerable evidence that muscle preloading contributes to greater force production (Asmussen, 1974; Bennett and Stauber, 1986; Bosco et al, 1982; Helgeson and Gajdosik, 1993; Komi and Bosco, 1978; Roy et al, 1990; Svantesso et al, 1991; Svantesson et al, 1994). Muscle preloading is commonly used during functional activities requiring maximum performance. For example, when an individual attempts to jump as high as he or she can, the individual first lowers him by flexing his hip and knee joints rapidly and then jumps. This has been shown to increase the height and distance of the jump and the maximal force production of the test muscle (Bosco et al, 1982; Komi and Bosco, 1978).

Mechanically, preloading stretches the elastic components of the muscle effectively storing potential energy, which is released during the subsequent concentric muscle action. Although several authors have investigated the effects of preloading prior to concentric force production, the primary emphasis has been on the mechanical effects of the stretch-shortening cycle of muscle which involves eccentric preloading (Bennett and Stauber, 1986; Helgeson and Gajdosik, 1993; Roy et al, 1990). An increase in the maximal muscle force production following preloading may also have a neural component. Maximal voluntary muscle activation is achieved through a combination of central and peripheral afferent feedback. When a muscle is dynamically preloaded by rapidly switching directions, the antagonistic muscle must eccentrically act to decelerate the preloading movement. Increased muscle spindle firing from the eccentrically acting muscle during the switch from preloading to the subsequent concentric action is a likely source of increased peripheral afferent feedback.

The velocity of limb movement is also a critical factor that involves an interaction between neural and mechanical mechanisms. In concentric movements, the ability of muscles to generate force decreases as the angular velocity increases (Caiozo et al, 1981; Gregor et al, 1979; Hill, 1922; Lord et al, 1992; Perrine and Edgerton, 1978). This is the well-known force-velocity relationship of muscle (Hill, 1922).

This decrease in concentric peak force with increasing velocity is believed to have a mechanical cause; a limitation in the cyclic formation of cross bridges (Edman et al, 1978). A neural mechanism, however, may also play a role in the decreasing peak force with increasing velocity of concentric movement. If primary afferent feedback contributes to the neural drive as Matthews has suggested, then the degree of this contribution may change as the velocity of muscle shortening increases. Muscle spindle discharge frequency decreases with increasing velocity of muscle shortening (Burke et al, 1978). Although intrafusal fibers increase the sensitivity of muscle spindles during concentric muscle activation via alpha-gamma coactivation, a relative unloading of the muscle spindles likely occurs at fast velocities of muscle shortening (Burke et al, 1978). The slower contracting intrafusal fibers lag behind the more rapidly contracting extrafusal fibers resulting in a decrease in spindle discharges from the muscle and less additive neural drive to the muscle when the muscle undergoes rapid concentric activation.

This study were to examine if an increased contribution of peripheral feedback was associated with the increased torque following preloading of the quadriceps muscle group, and to examine if the contribution of peripheral feedback to neural drive varied with the velocity of concentric movement. A basic assumption was that if subjects produced maximum voluntary effort, an increase in EMG activity with preloading represented additional neural drive from peripheral afferents. The specific aims were to:

1. Determine if increases in voluntary muscle torque following preloading of the quadriceps muscle group were the result of mechanical mechanisms alone or the combination of a facilitatory effect of peripheral feedback and mechanical mechanisms.
2. Determine if the force-velocity relationship under isokinetic shortening of the quadriceps was influenced by changing neural drive. That is, determine if the decrease in torque as the velocity of shortening increases was related to a decrease in electromyographic (EMG) activity due to a reduced proprioceptive facilitation.

There were two primary research hypotheses related to muscle preloading in this study. First, with preloading of the quadriceps, the peak maximal voluntary concentric torque would be significantly higher than the torque produced by non-preloaded knee extension. Second, when examining the preloaded condition, the associated quadriceps EMG would be significantly higher than the non-preloaded knee extension condition. Secondary hypotheses were that the initial 100 ms of quadriceps EMG (initial EMG) and the ratio of initial EMG to peak EMG would be significantly greater with preloading than without preloading.

Finally, when examining the un-preloaded single knee extension condition, the peak maximal voluntary concentric torque and the associated EMG activity of the quadriceps muscle would decrease as the velocity of the movement increase.

Literature Review

Muscle preloading

Several studies have suggested that the maximal concentric voluntary torque capability of muscle can be significantly increased by altering conditions prior to the muscle action (Asmussen, 1974; Bennett and Stauber, 1986; Bosco et al, 1982; Helgeson and Gajdosik, 1993; Komi and Bosco, 1978; Roy et al, 1990; Svantesson et al, 1991; Svantesson et al, 1994). For example, a preceding eccentric, concentric or isometric muscle action will increase voluntary torque capability of a muscle group action (Asmussen, 1974; Bennett and Stauber, 1986; Bosco et al, 1982; Helgeson and Gajdosik, 1993; Komi and Bosco, 1978; Roy et al, 1990; Svantesson et al, 1991; Svantesson et al, 1994). Although several authors have investigated the effects of eccentric preloading prior to performing a concentric maximal effort action (Bobbert et al, 1987; Bobbert et al, 1987; Komi and Bosco, 1978), they have focused on the mechanical effects of the stretch-shortening cycle of muscles. Komi et al (1978) found that the height of rise of the jump was higher when preparatory counter movement than when the jump was started from the squat position precedes a jump (Komi and Bosco, 1978). Concentric activation of the antagonist muscle can also increase the torque produced during the following concentric action of the agonist muscle. It was found that knee extension peak torque was higher when knee extension was preceded by a concentric knee flexion movement than when performed without preloading (Roy et al, 1990).

Mechanism of preloading induced increased torque generation

Torque produced by a muscle is dependent on a number of mechanical and neural factors. In the seated position, when the knee flexes and extends reciprocally, the quadriceps muscle undergoes an active stretch during the flexion period. Following concentric activation of the hamstrings, the quadriceps acts eccentrically to decelerate the knee when switching from flexion to extension. The increased voluntary torque produced by a preceding load is a result of a combination of mechanical and neural mechanisms. Bosco (1982) and Komi (1978) stated that the increased in performance in preloaded jump was attributed to a combination of elastic energy and myoelectrical potentiation of the muscle activation (Bosco et al, 1982).

The primary mechanism underlying the additional torque observed with a preceding agonist eccentric contraction and/or concentric antagonist muscle contraction is believed to be of mechanical origin (Asmussen, 1974; Helgeson and Gajdosik, 1993). Potentiation in force output is due to the storage of elastic energy in the elastic components of the musculotendinous structures during the eccentric phase which is then transformed into additional force to produce maximal voluntary torque during the subsequent concentric phase (Bennett and Stauber, 1986).

In addition to the mechanical mechanisms, neural mechanisms may also play an important role in increasing torque production. Maximal voluntary muscle activation is achieved through a combination of descending neural drive from supraspinal centers and peripheral afferent feedback. When peripheral afferent feedback is added to descending neural drive, total neural drive is increased and muscle force output is also increased. This has been termed proprioceptive facilitation technique and it is the basis for several physical rehabilitation techniques. Studies measuring EMG activity of the contracting muscle support the neural facilitation view (Jung, 1979). The three basic methods of proprioceptive facilitation are 1) stretching the muscle, 2) an eccentric muscle action prior to it's concentric action, a preloading, and 3) isometric activation of a muscle prior to it's concentric action.

Jung (1979) measured the reflex contribution to the EMG activity of the medial gastrocnemius muscle during gait. He suggested that after heel contact, a stretch of the medial gastrocnemius muscles be superimposed on an active medial gastrocnemius muscle. This stretch results in a reflex activation that is additive to the descending neural drive during gait producing greater EMG activity of the medial gastrocnemius muscle than does maximal voluntary activation alone. Jung (1979) believed that without the additive neural drive from the stretch, the visco-elastic spring action of muscle alone would not be enough to overcome the ground reaction force of walking. Similarly, Dietz (1978) found that the EMG activity from the triceps brachial muscle during falling is greater than during maximal voluntary activation of the same muscle.

Preloading the test muscle by an eccentric or isometric activation prior to the muscle action may also increase force production. Studies of eccentric preload have revealed increased force production during the subsequent concentric action (Bosco et al, 1982; Bobbert et al, 1987; Bobbert et al, 1987; Komi and Bosco, 1978). During an eccentric muscle action, intrafusal fibers in the muscle spindle are elongated, resulting in great muscle spindle afferent feedback to the alpha motor neurons (Burke et al, 1978). If a concentric muscle action is immediately preceded by an eccentric muscle action, the afferent feedback is received by the motor neuron during the subsequent concentric action. This is the basis of the well-known plyometric movements, which utilize counter movement to improve a performance requiring speed as well as power (Voight and Wieder, 1991).

Concentric preload may also influence force production as suggested by Roy

(1990). He speculated that the increase in maximal voluntary torque capability of the quadriceps when preceded by an antagonist muscle concentric contraction (knee flexion) is related to the enhanced sensory feedback. No evidence, however, was advanced to support this hypothesis. During the concentric action of the antagonist, the test muscle undergoes lengthening and the muscle spindles are elongated. Secondly, the muscle to be tested is eccentrically activated to decelerate the limb prior to it being concentrically activated. This increased proprioceptive input may facilitate the neural drive to the alpha motor neurons during the next concentric action of test muscle (Roy et al, 1990).

Force-velocity relationship

The velocity of limb movement is also critical to dynamic muscle action. The force-velocity relationship has been well studied in both isolated muscle preparation in vivo and using isokinetic dynamometers. In general, during isokinetic concentric action, as angular velocity increases maximum concentric torque decreases (Caiozo et al, 1981; Gregor et al, 1979; Hill, 1922; Lord et al, 1992; Martin et al, 1994). Furthermore, peak torque approaches zero as maximal velocity is reached (Perrine and Edgerton, 1978a, b). This decrease in maximum voluntary torque with increasing concentric velocity may be also due to a combination of mechanical and neural mechanisms. The mechanical factors which influence to the force-velocity relationship are muscle fiber type composition (Martin et al, 1994), cross sectional area, number of sarcomere in series, fiber number, fiber length, limitation in the cyclic formation of cross bridges (Edman et al, 1978), thermodynamics (Hill, 1922; Martin et al, 1994), and viscous resistance of the muscle substances and associated soft tissue to a rapid change of form (Hill, 1922; Martin et al, 1994). Although the major factors influencing the in-vitro force-velocity relationship are likely mechanical, the in-vivo force-velocity relationship of human muscle may also have a neural component. If primary afferent feedback contributes to the neural drive then the degree of this contribution as the velocity of muscle shortening increases.

Burke et al (1978) found increased discharge rates of spindle endings during concentric shortening muscle activation presumably due to alpha-gamma coactivation. As the speed of shortening increased, however, spindle discharge frequency was reduced (Burke et al, 1978). As a result of muscle spindle unloading which occurs due to the extrafusal fibers contracting more rapidly than the fusimotor fibers can increase spindle sensitivity, the muscle undergoing rapid concentric activation receives less additive neural drive. This would also decrease torque generation capability during high velocity concentric movements.

The in vivo force-velocity relationship of human muscle during isokinetic concentric action is also reverse relationship, however, it is different to the in vitro relationship as angular velocity approaches zero (Caiozo et al, 1981; Gregor et al, 1979; James et al, 1993; Lord et al, 1992; Perrine and Edgerton, 1978a, b). James et al (1993) found that when using isokinetic equipment, most subjects could produce maximal concentric torque when moving at velocities between 90°/s and 180°/s. However, with velocities greater than 180°/s or less than 90°/s, subjects were unable to produce as much torque (James et al, 1993). The drop off of maximum torque generation at slow concentric velocities has been confirmed by others (Caiozo et al, 1981; Caiozzo et al, 1989; Gregor et al, 1979; Perrine and Edgerton, 1978; Perrine and Edgerton, 1978). The lower capability to generate maximal torque when moving slower than 90°/s may be due to neural inhibition (Ostering, 1986). When great joint torque is produced by a muscle, increased sensory input from mechanoreceptors in the periarticular tissue inhibit the alpha motor neuron of the test muscle. Perrine et al. and Wickiewicz at al. also speculated that the force drop off at slow speed is related to the action of some neural regulatory mechanism (Perrine and Edgerton, 1978; Perrine and Edgerton, 1978; Wickiewicz et al, 1994). Again, no evidence has been advanced to support this hypothesis. Even though the mechanism of inability to generate maximum output during slow speed concentric activation in vivo condition is not clear, the level of torque production at the drop off point may present a kind of maximum safety tension level in-vivo under normal circumstances (Perrine and Edgerton, 1978).

Use of isokinetic testing for voluntary muscle contraction

Isokinetic testing has been found by some to be very reliable method of measuring torque production (Weir et al, 1992). The test retest reliability of peak torque (R=.96) and EMG measures (R=.95) during isokinetic knee muscle testing is high (Weir et al, 1992). In addition, the peak EMG activity and torque relationship of knee extensors is highly linear (r^2 ranged from .81 to .98) (Weir et al, 1992). Roy et al (1990), however, demonstrated a learning effect when using isokinetic devices to measure knee extension torque (Roy et al, 1990). He found that when subjects perform repeated isokinetic muscle tests, their performance varied across days (Roy et al, 1990). When test results were compared across three consecutive days, significant differences between the first and second days existed, however, differences rarely existed between the second and third days (Roy et al, 1990). Therefore, in order to provide subjects with ample time to learn the tasks, the subjects in this study will undergo a practice session two or three days prior to testing.

Methods

Subjects

Sixteen healthy volunteer subjects (10 male, 6 females); aged 22 to 28 (28.5±1.52) years old were studied. They were not engaged in a competitive physical training program. Exclusion criteria included any diagnosis requiring a physician's care for any orthopedic, neurologic or systemic illness. All subjects signed an informed consent form approved by the Institutional Review Board at the University of Florida Health Science Center prior to their inclusion in the study. All 20 subjects completed the study, and all of the data were used for statistical analysis.

Instrumentation and experimental setup

A Cybex II isokinetic dynamometer[1] was used to measure the torque (a dependent variable) produced during maximal voluntary knee extensions by concentric contraction of the quadriceps femoris muscle group of the subject's dominant leg. The Cybex II dynamometer provided the subjects with isokinetic resistance to knee extension at 100°/s, 200°/s, and 300°/s for this study.

The testing procedure required the subjects to be seated on a padded bench with the thigh of the test leg and trunk strapped to the bench to prevent unwanted motion. A padded ankle cuff was placed on the ankle just proximal to the medial malleolus. The cuff was attached to the lever arm of the isokinetic dynamometer. The angle between trunk and thigh was approximately 120° Subjects flexed and extended the dominant knee through a range of 0° to 110°.

Surface EMG from the vastus medialis (VM) and vastus lateralis (VL) muscles (dependent variables) was recorded using bipolar Ag-AgCl surface electrodes[2] during maximal concentric voluntary knee extension. These electrodes have a high input resistance (>15 mega ohms at 100 Hz) and are embedded in an epoxy mounted with preamplifier circuitry and a 2-centimeter inter-electrode distance. The preamplifier has a gain of 35X, and a second stage amplifier provided a total amplification of 5 K with a lower frequency cutoff of 20 Hz. These electrodeshave a high signal-to-noise ration (noise < 2 microvolts; common mode rejection 87 db at 60 Hz) and no significant movement artifactwhen secured with adhesive electrodecollars and when foam tape is wrapped over the electrode and around the thigh. The torque signal from the Cybex and the EMG data were sampled at 1 kHz, stored and later analyzed with a commercially available data acquisition system[3] and a personal computer.

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[1] Cybex, Ronkonkoma, NY. U.S.A.

[2] Therapeutics Unlimited, Iowa City, Iowa, U.S.A.

[3] Data Pac III

Testing protocol

Subjects were given two tests with a 2-3 day interval between tests. On test day 1, each subject had a 20 minute sub maximal practice session prior to testing to get accustomed to the equipment and to the procedure. Visual feedback of force production using an oscilloscope was provided to the subjects during the practice session. Subjects had a 5-minute rest period before starting the testing. The purpose of test day 1 was to assess the test-retest reliability of the torque measurement; EMG data, therefore, were not collected on test day 1. Except for having a practice session prior to the test session and not measuring EMG data, the procedures of the testing on test day 1 were the same as on test day 2.

Subjects underwent a 45-minute isokinetic strength test on each test day. A five-minute sub maximal warm up was given to subjects before testing on test day 2. They were asked to produce maximal efforts and to complete the entire range of motion during both their practice and test sessions. The researcher provided subjects with directions regarding when to start and stop. Subjects were encouraged verbally to produce their maximum effort during each trial. They were not told the results of trials during testing.

Subjects were tested under six different conditions (3 velocities 2 activation conditions) with three-minute rest periods between conditions. The order of testing was counter balanced to avoid order effects. The order of testing on Test 1 and test 2 remained the same for each subject. The Velocities of motion for the isokinetic strength testing were 100°/s, 200°/s, and 300°/s. The two activation conditions were an un-preloaded single concentric (UPL) condition and a preloaded reciprocal (PL) condition.

Subjects performed 5 trials for each of the six conditions with 10-second rest between trials and 3 minute rest between conditions. The UPL condition was single, isolated, maximal, concentric knee extension movement. The test started with the subject's knee in 110° of flexion. At a "go" signal, subjects were asked to straighten their dominant knee to 0° as hard and as fast as they could against the resistance and then relax to bring their leg back to the starting position. They will perform 3 trials with 15 second rest between trials.

The PL condition was single isolated knee extension following knee flexion preload. This assessed the effect of preceding concentric antagonist muscle action at three different speeds. The test was started with the knee in full extension. When cued, the subjects flexed their knee to 110°, then extended with maximal effort back to the start position, and finally relaxed allowing their knee to flex again. Subjects were told to choose their own speed and amount of effort for the preceding flexion movement and their primary goal should be to produce a maximal knee extension force.

A rapid turn around from flexion to extension, however, was encouraged for the PL condition.

Statistical analysis

The independent variables were the velocity of movement (100°/s, 200°/s, and 300°/s) and the muscle activation condition (UPL condition and PL condition). The dependent variables were the peak knee extensor torque and the peak and RMS EMG from VM and ML during the maximum voluntary concentric quadriceps contraction. Each measure represented the mean of 5 trials obtained under each condition and speed. The peak EMG represented the peak RMS average of the EMG from the onset to offset of each movement.

To assess the test-retest reliability of measuring the subject's ability to produce a maximal effort on the isokinetic dynamometer, an intraclass correlation coefficients (ICCs) was calculated from the test day 1 and test day 2 data using a 2-way (subject x trial) ANOVA.

To determine the effects of quadriceps muscle preloading and the effects of velocity of muscle shortening, the data from test day 2 were statistically analyzed using 2 X 3 (activation condition x velocity) repeated measures ANOVAs for each dependent variable. Simple contrasts were used to identify differences between specific velocities when the velocity effect was significant. All tests were made using a $p<.05$ level of significance.

Results

Test-retest reliability

The test retest reliability between test day 1 and 2 was relatively high, as indicated by a high ICC=.928 between the peak torque on the first and second tests.

Effects of quadriceps muscle preloading and the velocity of movement

There was no significant muscle activation condition by velocity of movement interaction on peak torque, peak EMG, and RMS EMG (Table 1)(Figure 1, 2).

Table 1. Means and standard deviationsof the peak torque and the percent difference between the PL condition and UPL condition (N=16)

Velocity (°/s)	Torque Day 2		Diff Torque (%)
	UPL condition	PL condition	
100	2.306±.144	2.439±.159	5.77
200	1.943±.125	2.082±.135	7.15
300	1.445±.110	1.574±.114	8.93
Mean and SD	1.898±.121	2.032±.131	7.10

Diff indicates percent difference.

There were, however, significant main effects for muscle activation conditions on all 5 dependent variables. As expected, the peak torque was significantly greater (F(1,16)=42.71; p=.000) with the PL condition as compared to the UPL condition (Table 1)(Figure 1). The RMS VM EMG (F(1,16)=5.662; p=.030), RMS VL EMG, (F(1,16)=4.459; p=.049), peak VM EMG(F(1,16)=12.846; p=.002), and peak VL EMG (F(1,16)=7.594; p=.014) were also significantly greater with the PL condition as hypothesized (Figure 2).

There was a significant main effect of velocity of movement on peak torque (p<.001). The peak torque progressively decreased as the velocity of movement increased from 100°/s to 200°/s, and from 200°/s to 300°/s (p=.000)(Table 1)(Figure 1). There were, however, no main effects for velocity on the RMS and peak EMG amplitude.

Discussion

In support of the research hypotheses, the major finding of this study was that the peak maximal voluntary concentric torque was significantly higher when the quadriceps was preloaded. This is consistent with the results of other studies that have investigated the effect of muscle preloading on maximal torque (Asmussen, 1974; Bennett and Stauber, 1986; Bosco et al, 1982; Helgeson and Gajdosik, 1993; Komi and Bosco, 1978; Roy MA et al, 1990; Svantesson et al, 1991; Svantesson et al, 1994). In support of the second hy-

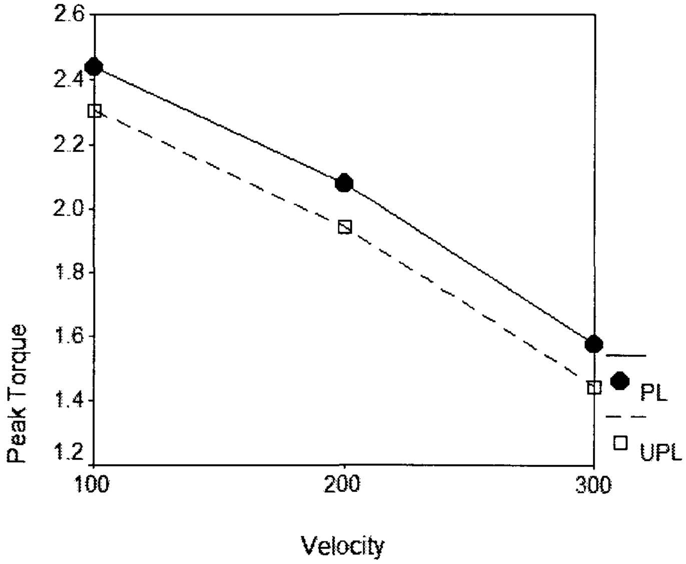

Figure 1. Line graph comparing the peak torque with the PL (preloaded) and UPL (un-preloaded) conditions across the three velocities of movement

pothesis, the associated quadriceps EMG activity was also significantly higher with preloading. Moreover, this torque increase was significantly related to peak torque. These results support Roy et al.'s speculation that the increase in maximal voluntary torque capability of the quadriceps when preceded by an antagonist muscle concentric contraction (knee flexion) is in part related to a neural facilitatory mechanism. The findings of this study support the view that increases in voluntary muscle torque following muscle preloading of the quadriceps muscle group are a combination of both mechanical and neural mechanisms.

As we hypothesized, when examining the un-preloaded knee extension condition, the peak maximal voluntary concentric torque of the quadriceps muscle decreased as the velocity of the movement increased. This result is well-known

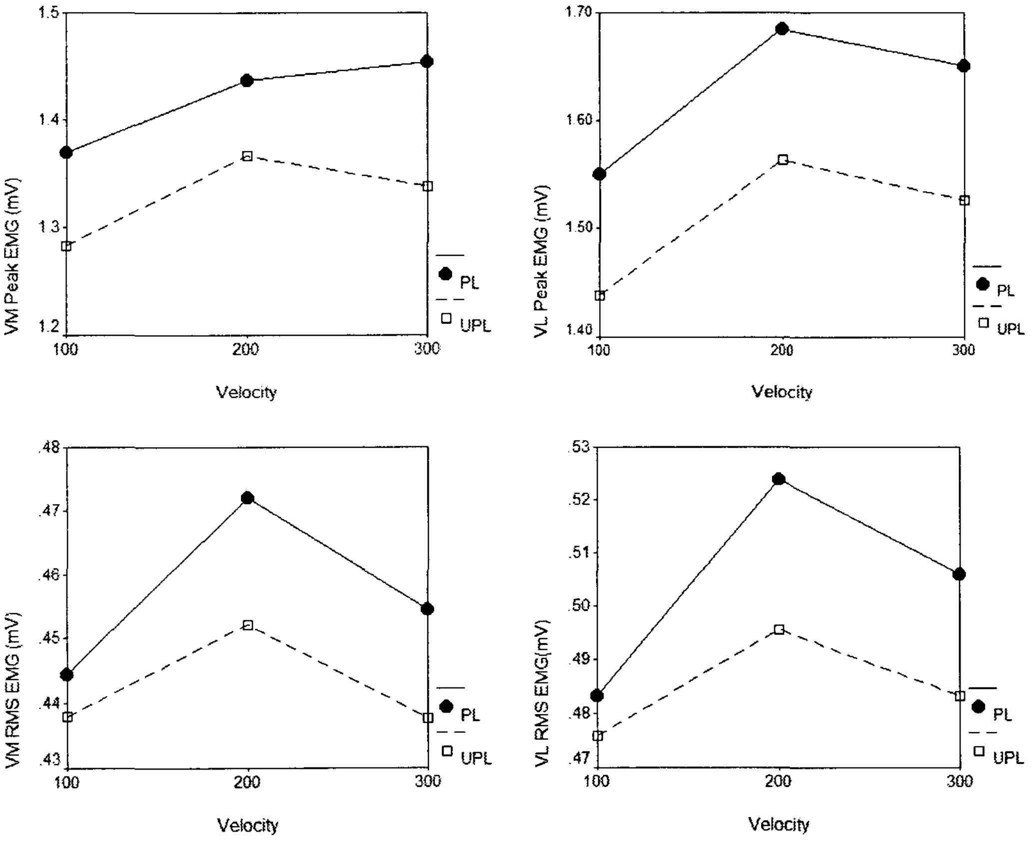

Figure 2. Line graph comparing the EMG amplitudes with the PL (preloaded) and UPL (un-preloaded) conditions across the three velocities of movement
peak VM EMG (upper left) peak VL EMG (upper right)
VM RMS EMG (lower left) VL RMS EMG (lower right)

force-velocity relationship (Caiozzo et al, 1989; Gregor et al, 1979; Hill, 1922; Lord et al, 1992; Martin et al, 1994). James et al (1993) found that most subjects could produce maximal knee extensor torque when concentrically moving at speeds between 90°/s and 180°/s. Consistent with the finding of James et al (1993), our results showed the greatest peak torque at the slowest velocity, 100°/s (Figure 1)(Table 1).

In contrast to peak torque and our hypothesis, the associated peak EMG of the un-preloaded knee extensor muscle did not decrease linearly as a fraction of the velocity of the movement (Figure 2). We have theorized that if spindle afferent feedback contributes to concentric force, with increasing velocities of movement there may be a decrease in EMG due to an inability of the slower intrafusal muscle fibers to maintain spindle sensitivity (Burke et al, 1978). There was a tendency for the peak EMG to decrease from 200°/s to 300°/s which would have support our hypothesis, however, there was also decreases in peak and RMS EMG activities from 200°/s to 100°/s concentric velocity (Figure 2). This later decrease in EMG may have been due to neural inhibitory mechanism (Perrine and Edgerton, 1978a, b). Thus two opposing neural mechanisms may have been operation. A future study should involve a greater spectrum of velocities to assess whether one or both these mechanisms are present.

Conclusion

The findings of this study demonstrates that muscle preloading by a concentric action of the hamstrings can defectively facilitate both the level of quadriceps activation and the knee extension torque produced. This is an evidence of facilitatory effect on the neural drive to active agonist muscle by preceded concentric contraction of antagonist, not just a mechanical effect on torque output. This would support the proposed mechanism of proprioceptive neuromuscular facilitation techniques of Knott and Voss (1953).

Coordinated reciprocal contractions of antagonistic muscle represent a component of many functional tasks such as kicking a ball and riding a bike. The findings of this study also may be generally useful in rehabilitation and muscle performance training situations in which neuromuscular facilitation is desired. With training involves preloading concept, individuals may enhance their ability to facilitate strong and explosive muscle activation by having preloading contraction in efficient manner.

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