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Muscular Co-Activation of the Knee Flexor-Extensor Muscles During Multi-Directional Perturbations

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Abstract: *Aim*: The purpose of this study was to investigate co contraction pattern of knee flexor-extensor muscles during multidirectional destabilizing knee perturbations. Thirteen healthy men (mean ± SD; age = 24.2 ± 2.2 yr) without previous knee injury participated in the study. Surface EMG signals were recorded from seven locations distributed over the knee flexor and extensor muscles by circular Ag- AgCl surface electrodes (Ambu Neuroline, conductive area 28 mm^2) during unexpected knee perturbation in backward-forward, medial-lateral and downward directions. Results revealed that muscle reflex activity was dependent on muscle ($P < 0.05$) perturbation direction ($P < 0.05$) and interaction between muscle and perturbation direction ($P < 0.05$). The amplitude of EMG in backward direction was significantly larger than other directions ($P < 0.05$). The amplitude of EMG of the lateral head of gastrocnemius, semitendinosus, vastus lateralis and vastus medialis muscle were larger in backward direction compared with four other directions ($P < 0.05$). Likewise, vastus lateralis, semitendinosus and the lateral head of gastrocnemius produced larger EMG amplitude in forward direction ($P < 0.05$). However the EMG activity of the knee muscle was not significantly different between medial, lateral and downward perturbations ($P > 0.05$). In conclusion these results indicate that central nervous system use different neural strategies in activating muscles around knee joint during postural perturbation in the saggital plan that challenges knee stability.

Key words: EMG Activity · Postural Perturbations · Knee Muscles Co-Activation

INTRODUCTION

Maintenance dynamic stability of the knee joint is dependent on reflex muscle activity around knee joint to return a perturbed knee joint to normal anatomic position. Reflex muscle responses to rapid perturbations play a significant role in the dynamic alignment and stability of musculoskeletal structures. Previous study elicited reflexive responses in knee muscles by mechanical stimulation of the medial ligament [1] and by a rapid valgus/varus movement of the knee [2] and they found these reflexive responses can enhance knee stability. Other published literatures have also confirmed that joint stability is dependent on the cortically programmed muscle activations and reflex-supplied muscle contractions [3]. Moreover, it is well documented that co-contractions of the knee flexor- extensor muscles play an important role in knee joint stability, in response to external stresses [4]. In fact, sensory receptors in the anterior cruciate ligament (ACL) and capsule produces reflex arcs that are known to tirgger synergistic action of the antagonist hamstrings during knee extension [5]. In agreement with this, Baratta *et al*. reported that muscular co-activation mediated by ligament receptors as being crucial for knee stability [4]. These authors suggest that co- contraction of muscles around knee joint would not only contribute in greater joint stiffness but would also increase and regulate the contact of knee joint surfaces. Likewise Johansson *et al*. proposed that muscle spindle contribute to muscle co-contraction through sensory information from muscles, ligaments, the joint capsule and skin and that this mechanism might serve to increase joint stability [5]. Previous studies have investigated co-contraction of the knee flexor - extensor muscle in sagittal plan during walking [6], jumping [7], isotonic and isokinetic knee extensions [8]. However there are no studies that have investigated knee flexor- extensor co contraction during multidirectional postural perturbation that challenge knee stability. Examination of the knee flexor and extensor co contraction during multidirectional

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perturbations may provide more insight into the muscle activity patterns around knee joint during demanding tasks that challenge knee stability. Thus the aim of this study was to investigate co contraction pattern of knee flexor-extensor muscles during multidirectional destabilizing knee perturbations.

MATERIALS AND METHODS

Subjects: Thirteen healthy men (mean ± SD; age = 24.2 ± 2.2 yr, body mass = 76.5 ± 5.4 kg, height = 1.76 ± 0.05 m) participated in the study. All subjects were right leg dominant and had no history of previous knee injury.

Electromyography Recording: Surface EMG signals were recorded from knee flexor and knee extensor muscles by circular Ag- AgCl surface electrodes (Ambu Neuroline, conductive area 28 mm^2). For knee extensor muscles, the electrodes were placed in bipolar configuration (interlectrod distance 2-cm) over the most distal portion of the vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL). For knee flexors the electrodes were positioned over the medial (long head of biceps femoris) and lateral (semitendinosus) belly of hamstring and over the medial and lateral head of the gastrocnemius muscle. Before electrode placement, the skin was shaved and lightly abraded at the selected locations.

Perturbations and Surface EMG: The subject stood comfortably with equal weight on each limb and their right limb on a movable platform. The subject's left foot was positioned on the ground. Platform was translated 6 cm frontally (forward and backward direction), sagittally (medial and laetal direction) and in downward direction. Two 3-s trials were collected in which the plate was triggered to move at a random interval within the 3 s. Subjects were unaware of when the plate would be triggered to move. Surface EMG signals were recorded from the knee flexor and extensor muscles of the right limb.

Signal Analysis: Surface EMG signals obtained from seven knee muscles were amplified (EMG amplifier (EMG-128; LISiN-OT Bioelettronica, Turin, Italy; bandwidth of 10-500 Hz), sampled at 2048 Hz and stored after 12-bit A/D conversion. To assess the amplitude of muscle reflex activity, the ARV of individual muscles was calculated over a fixed window, which was 180 ms after the onset of plate movement (monosynaptic stretch reflex). The ARV obtained from the 180-ms epochs in two trials were averaged to obtain a representative value.

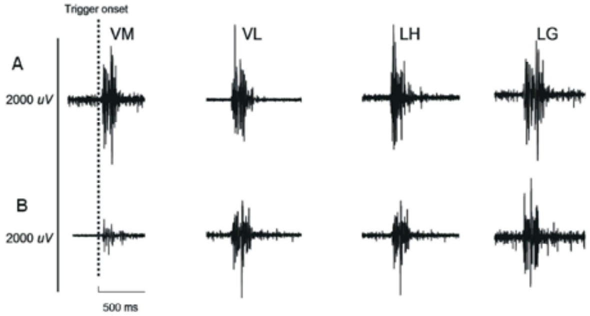

Fig. 1: An example of surface EMG signals recorded form vastus medilais (VM), vastus lateralis (VL), lateral hamstring (LH) and lateral gastrocnemius (LG) of one subject during backward (A) and forward perturbation (B). Signal was recorded after the onset of plat movement

Statistical Analysis: Tow-way analysis of variance applied to measure muscle reflex activity with muscle and perturbation direction as dependent factors.

RESULT

Muscle reflex activity was dependent on muscle (F= 2.6, P <0.05) perturbation direction (F= 4.4, P <0.05) and interaction between muscle and perturbation direction (F= 2.4, P <0.05). The lateral head of the gastrocnemius muscle, vastus lateralis and lateral hamstring (semitendinosus) resulted in larger EMG amplitude than others muscle (P < 0.05). The amplitude of EMG in backward direction was significantly larger than other directions (P < 0.05).

Moreover the amplitude of EMG of the lateral head of gastrocnemius, semitendinosus, vastus lateralis and vastus medialis muscle were larger in backward direction compared with four other directions (P < 0.05). However, vastus lateralis, semitendinosus and the lateral head of gastrocnemius, produced larger EMG amplitude in forward direction (P <0.05). Whereas, the EMG activity of the knee muscles was not significantly different between medial, lateral and downward perturbations (P > 0.05).

DISCUSSION

The result of the current study showed that the Co- contraction of the knee muscle in backward and forward perturbation directions were significantly higher than medial, lateral and downward directions. The highest Co-contraction of the knee muscle in backward-forward direction may indicate that higher muscle activation around knee joint is required to stabilize knee joint in

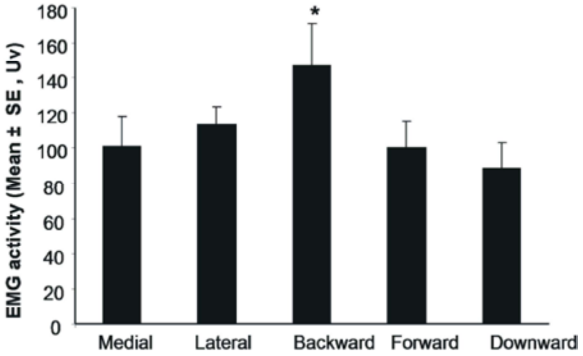

Fig. 2: EMG activity of knee muscles (averaged for knee flexor and knee extensor muscles) (subjects, N= 13) during postural perturbation at different directions. *P <0.05

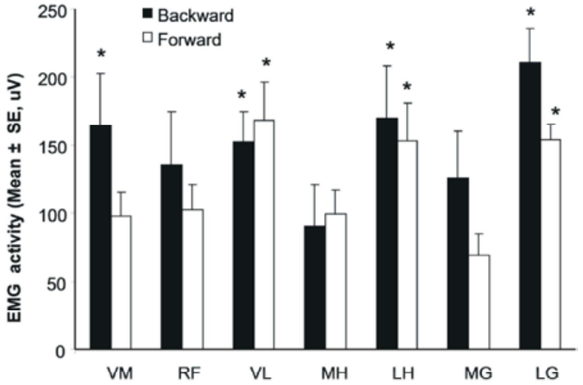

Fig. 3: Co-activation of knee muscles (subjects, N= 13) during postural perturbation in forward and backward directions. *P <0.05

sagittal plan. These results suggest that central nervous system use different neural strategies to stabilize knee joint in different perturbation directions.

EMG and Perturbations: In this study we observed that the EMG amplitude of the knee muscle were dependent on perturbation directions. The amplitude of EMG of the lateral head of gastrocnemius, semitendinosus, vastus lateralis and vastus medialis muscle were larger in backward direction. However, vastus lateralis, semitendinosus and the lateral head of gastrocnemius muscle generated highest EMG amplitude in forward direction. While no significant differences in EMG activity observed between knee muscles in medial, lateral and downward perturbations. The highest EMG amplitude observed in knee muscle during backward-forward perturbation direction may suggest that a higher level of co-activation of the knee flexor-extensor muscle is required to stabilize the knee joint during unexpected perturbation in the sagittal plan. Pervious studies have also reported that co- activation of the agonist-antagonist muscle act as mechanism to increase joint stability during daily activity such as walking [6], jumping [7] and stepping task [6]. Hansen *et al*. has defined this mechanism as in-phase coupling system, in which agonist and antagonist muscles are co-activated without any opposing inhibition [9]. Central nervous system most probably uses this neural strategy to simultaneously activate muscle around joint, where co-activation is essential in order to increase the joint stability. In the current study, the observation that muscle activity for the lateral head of gastrocnemius, semitendinosus, vastus lateralis and vastus medialis muscle were larger in backward-forward perturbation directions compared with other three perturbation directions can be related to the type of muscle action and time duration of the action [10]. During knee flexion- extension movement in the saggital plan, concentric knee extensor muscle contraction is accompanied by various degrees of eccentric knee flexor contractions [11]. Rapid movements such unexpected postural perturbations in the saggital plan are associated with large knee flexor co-activation as reported in previous studies [12]. During knee perturbation the knee extensor muscles is primarily responsible for knee extension and the knee flexor muscles provides an effective means of knee extension deceleration [13]. Since, postural perturbation in the saggital plan is characterized by higher activation of the knee extensor muscle to return the knee joint to normal position, therefore a higher level of antagonist co-activation is required to decelerate knee extension movement. In agreement with our findings, McFadyen and Winter reported that coactivation pattern of agonist-antagonist knee muscle during the ascent phase of the stair-stepping task was different than the descent phase [14]. They observed that vastus lateralis, semitendinosis, medial gastrocnemius and soleus muscle but not rectus femoris had greater activity for ascent phase as compared to descent phase. This co-contraction of the knee flexor and extensor muscle has been proposed as mechanism to maintain joint stability and prevent damage to the ligaments [15-16]. Pervious literature has also confirmed that knee flexor co-contraction serves to relieve strain in the ACL elicited by quadriceps contraction [17-18]. Hamstrings co-contraction can also prevent anterior or rotary displacement of the tibia and reduce rotary laxity of the knee [19-20].

CONCLUSION

This study showed that coactivation pattern of the knee flexor-extensor muscles in backward- forward direction (saggital plan) was different from the other three perturbation directions. The amplitude of EMG of the lateral head of gastrocnemius, semitendinosus, vastus lateralis and vastus medialis muscle were larger in backward-forward direction as compared with other three directions. These results indicate that central nervous system use different neural strategies in activating muscles around knee joint during postural perturbation in the saggital plan that challenges knee stability. This knowledge may be useful to design an exercise program to prevent knee injury/and or providing effective treatment after knee injuries.

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