

THE PATTERN OF MODULATION OF SHORT LATENCY REFLEX LINKING THE PRETIBIAL MUSCLES TO THE KNEE EXTENSORS DURING GAIT IN HUMAN

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ABSTRACT

Objective: To find out pattern of modulation of heteronymous reflex linking the pretibial muscles to quadriceps motoneurons in normal subjects during treadmill walking.

Methodology: A non-randomized quasi-experimental study was performed in ten cases in Shahid Beheshti University (MC) Tehran, Iran, from September 2006 to August 2007. The reflex was elicited by applying stimuli of three times motor threshold in tibialis anterior to common peroneal nerve at several instants of gait cycle. Surface EMGs from tibialis anterior, vastus medialis and rectus femoris of the right leg was used to measure the intensity of the muscular activity and the magnitude of the reflex. The data were analysed by Pearson test for the strength of their correlation.

Results: The reflex showed a significant correlation with the intensity of contraction in quadriceps especially during the early stance phase. The correlation was poor during transition period from stance to swing where rectus femoris showed a small peak of activity. The peak of activity in tibialis anterior was on average 69 ± 21 ms preceded that of quadriceps.

Conclusions: This precedence of activity in tibialis anterior and the strong presence of the reflex during the early stance phase may indicate a positive feed-forward effect from ankle flexor afferents to quadriceps.

KEY WORDS: Quadriceps, Pretibial muscles, Feed forward, Reflex.

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INTRODUCTION

There is increasing evidence that group I and II excitatory pathways play a crucial role in the control of bipedal stance and gait. In contrast to the group I projections which are weak and unlikely to provide strong reflex support, the group II excitatory pathways play a crucial role in the control of bipedal stance and gait.¹⁻³

It is believed that the EMG adjustments during stance and gait in humans are related to the demands of equilibrium control and group II projections have a major role in this adjustment. This adjustment can be twofold:

1. To control the upright balance in the lower

limb to the changes in the position of the centre of mass to the feet.^{4,5}

2. To enforce the activity of the antigravity group of muscles in order to prevent the yielding of the joints during stance phase of gait. This positive feedback input ensures the stability of the lower limb and the upright position during stance.

In man, stimulation of the common peroneal nerve (CPN) has been shown to evoke biphasic excitation of quadriceps (Q) motoneurons⁶ with the earlier phase attributed to non-mono-synaptic group I and the later phase to group II afferents. It has been shown that the interneurons in this reflex pathway are the convergence point for different ascending⁷ and descending⁶ regulating pathways. The concept that this reflex pathway could be modulated by different descending and ascending inputs could suggest its important role in reflex adjustments to perturbations during upright stance and gait. The role of this neural pathway in motor control of Q would be more prominent when we consider its contribution to spasticity and rigidity in hemiplegic⁸ and parkinsonian⁹ patients respectively.

Transmission of group II excitation from pretibial muscle receptors to quadriceps motoneurons is enhanced when the two muscles are active either after heel strike during walking¹⁰ or when leaning backwards in bipedal stance.¹¹ It was concluded that this reflex helps the stability of the knee by enforcement of the activity of Q during early stance phase.

There is not enough information about the pattern of modulation and the temporal correspondence of this reflex with Q activity during the whole gait cycle in the literature. The pattern of modulation of this reflex could provide more information about the mechanisms involved in the motor control of normal gait.

This study was therefore conducted to investigate the pattern of modulation of this reflex during walking and its correlation to the intensity of the background muscular activity.

METHODOLOGY

Ten volunteers (25±5 years of age, 5 female and 5 male) were enrolled in the non-randomized quasi-experimental study in September 2006 and it was accomplished in August 2007 in Shahid Beheshti University (MC), Tehran, Iran. None of the subjects had any history of neuromuscular injury or systemic disease. Approval was obtained from local ethical committee.

Electrical stimuli were applied to the common peroneal nerve at caput fibulae during treadmill walking. The intensity of the stimuli was set at 3×MT in TA. To compensate the possible relative movement of the electrodes and the common peroneal nerve the MT was measured separately at all the selected instants of the gait cycle. Surface EMGs were recorded from TA, vastus medialis (VM) and rectus femoris (RF) of the right leg. Each set of experiment consisted of 3-5 minutes continuous EMG recording during which 40 stimuli were applied in pseudo-random sequences.

Two small pressure switches (1cm x 2cm) were located under the heel and at the toe region of the sole of the right shoe to identify the start and the end of the stance phase of gait. The trigger pulse from the heel switch passed through a digital delay width module (NL 401, Digitimer Ltd, Hertfordshire, England) in order to adjust different delays for the stimulator.

The experiment started with about five minutes of familiarising walking on the treadmill. The speed of the treadmill was set to a comfortable value (.3.5 to 4.5km/h) and Sets of recordings were done with stimulation at different delays from the heel strike. Delays of 0, 50, 100, 150, 200, 300, 500, 700, 900, 1000, 1100ms after heel strike were selected. Since the duration of the gait cycle among the subjects was almost similar (1165 ± 50ms), stimuli happened at almost similar points in the gait cycle with all pre-selected delays. In each set of recordings the intensity of muscle EMG activity was calculated by averaging the RMS of 30ms post-stimulus period in raw control EMG

and was expressed as the percentage of the MVC.

The MVC of RF and VM was calculated from the averaged RMS electromyogram (EMG_{rms}) of three maximum contractions at the start of each experiment. The EMG_{rms} of 10-second rest period before the maximum contraction was set as an offset to compensate for the background noise. The global peak to peak amplitude of the reflexes at each stimulus delay of stimulation was measured from the non-rectified average of 40 EMG samples and was expressed as percentage of the MVC. Correlation between the magnitude of the reflex and the intensity of VM and RF activity was analysed by Pearson correlation coefficient test.

RESULTS

RF and VM had a very similar pattern of EMG activity (Fig-1). Both muscles were active from terminal swing to midstance. Their contractions start from about 75% and 87% of gait cycle for RF and VM respectively. The peak of activity for RF and VM happens early after heel strike at about $4\% \pm 2\%$ of gait cycle for both muscles. The peak of RF activity ranged from 13% to 39% of MVC with the average of 19%. VM peak contraction intensity ranged from 17% to 40% and with a mean of 25%. EMG activity dropped slowly to its lowest level at mean 25% of gait cycle for VM and 17% for RF.

In five out of ten subjects investigated in this experiment, RF showed a second small peak of activity ($6\% \pm 2\%$ of MVC) at the end of the stance phase between 55% and 70% of gait cycle.

Tibialis anterior also showed a burst of activity started shortly before heel strike with its peak at $2\% \pm 2\%$ of gait cycle. The peak of activity in TA was in average 69 ± 21 ms earlier than that of VM and RF. Its activity dropped steeply to almost rest level early after about 5% of gait cycle and remained silent during the remaining stance phase. Another peak of activity but of lower intensity started at the start of the swing phase. It remained active at low intensity during the swing phase.

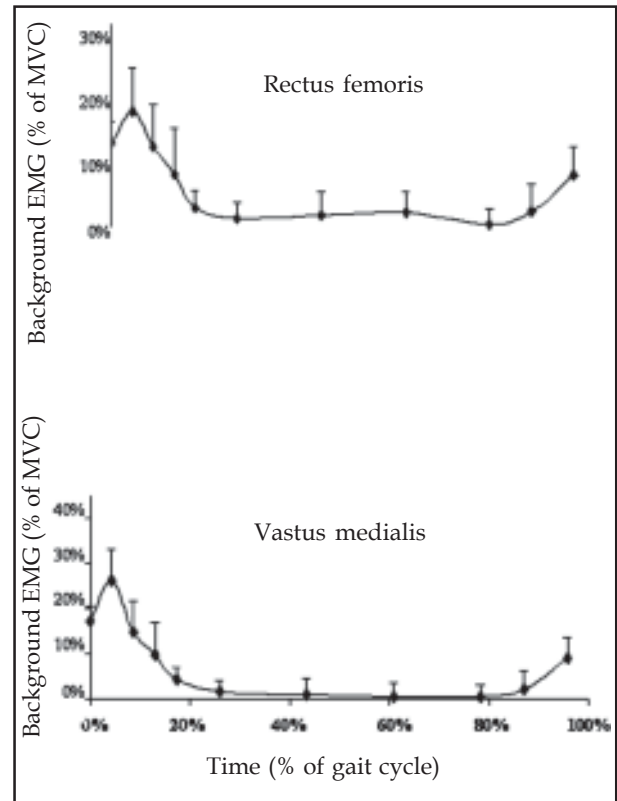


Figure-1: The pooled intensity of the EMG for VM and RF during gait cycle

Modulation of CPQ reflex amplitude during gait: Electrical stimulation, at an intensity of $3 \times MT$ in TA evoked double peak reflexes in VM and RF. The global peak to peak amplitude of the reflexes in both muscles changed similarly during gait. The reflex was at its maximum magnitude between the terminal swing and early stance phase (Fig-2). It can be seen that the magnitude of the reflex reaches its maximum early after heel strike. The average global peak intensity of the reflexes at this period was 70% MVC for RF and 121% of MVC for VM. The magnitude of the reflex then decreases gradually to an areflexic state which lasts until the terminal swing phase. The reflex appears again during terminal swing (at 90% and 95% of gait cycle for VM and RF).

A strong and positive correlation was found between the magnitude of the reflex and the intensity of the quadriceps activity throughout the gait cycle ($r = 0.88$ for VM and $r = 0.80$ for RF) (Fig 3).

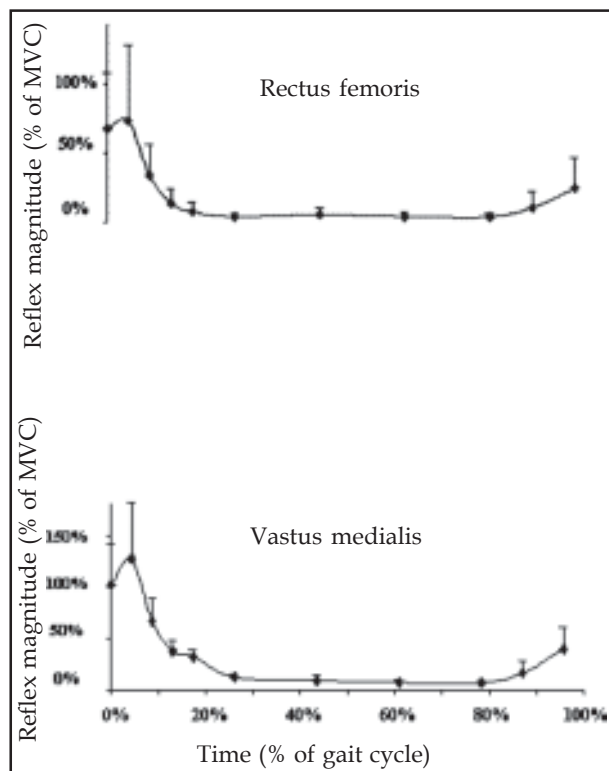


Figure-2: The mean amplitude of the CPQ reflex in RF and VM during the gait cycle

DISCUSSION

The global reflex magnitude was at its highest shortly after heel strike however, during most of gait cycle from midstance to terminal swing no reflexes could be elicited. Figure-3 clearly shows the strong linear correlation between the pattern of changes in the reflex magnitude and the intensity of EMG activity in RF and VM. The activity of the VM and RF muscles reaches the peak of about 20% of MVC after heel strike. The positive correlation between the background EMG of quadriceps and the magnitude of the reflex during the early stance phase may suggest an automatic gain compensation described by Matthews¹² in 1986 for the monosynaptic stretch reflex. It was argued that as the background force increases so does the number and the frequency of the active motoneurons available to be modulated by a given input. It is obvious that descending inputs have an excitatory effect on this pathway.^{13,14} Indeed, a minimum descending input is needed for the appearance of the reflex. The

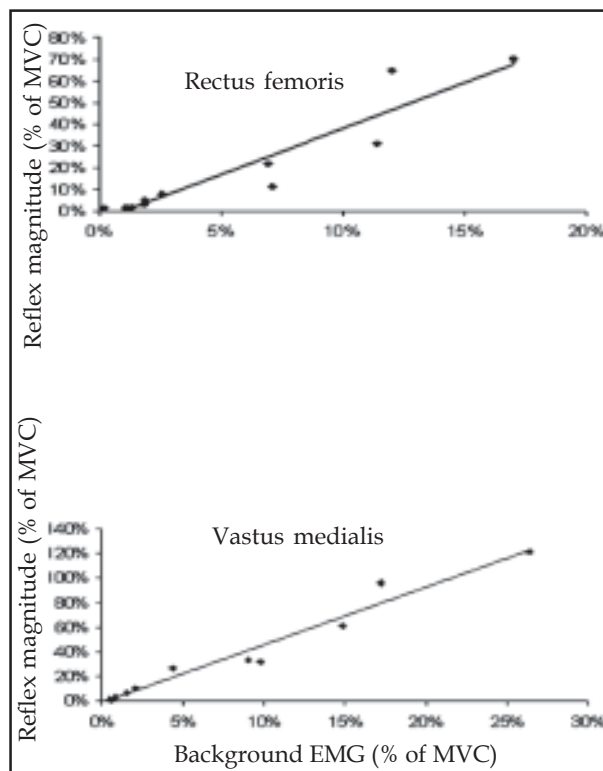


Figure-3: The correlation between the magnitude of the CPQ reflex and the intensity of the background EMG in VM and RF during the whole gait cycle

strong presence of the reflex during early stance phase is consistent with that reported by Marchand-Pauvert and Nielsen.¹⁰

The strength of the reflex at early stance which coincides with the peak of activity in TA and also Q could reflect a reinforcing effect from ankle dorsiflexors to the knee extensors. The precedent activation of TA to Q may suggest a feed forward type of effect from the pretibial muscles. This could provide the Q with the information about the load and helps the stability of the knee joint during this loading period of gait. It is likely that this reflex could quantitatively control the activity of Q during early stance phase in reaction to the load imposed on the foot.

Careful attention to the figure three reveals that the most of the points on the regression line are positioned near zero. This is because during the greater period of the gait the background EMG and expectedly the reflex are at near zero values. If the changes in the back-

ground activity in VM and RF are responsible for the gain modulation of the CPQ reflex during gait, it would be expected that increasing the background EMG activity during this long quiescent period would cause the reflex to reappear.

Interestingly, half of the subjects investigated in this experiment showed some EMG activity during the transition period from stance to swing phase in RF. This has also been reported in other investigations.¹⁵ The intensity of the background activity at this period was as high as 8% of MVC. This could be enough background activity to elicit the reflex. Despite this background activity no reflexes were detected during this period. This raises doubts about the actual nature of the reflex modulation during this areflexic period. In fact, for this group of subjects, the correlation between the reflex magnitude and the intensity of background EMG is very weak during this period of gait. It is not clear whether the absence of this excitatory effect during this period of gait cycle is a result of simple disfacilitation or an imposed inhibition.

Recent experiments in cat and man have demonstrated that afferent feedback from ankle extensors contributes to the activation of ankle extensor muscles in the stance phase of walking.^{16,17} In the cat, the termination of the stance phase and the initiation of swing phase are signalled by the decrease in afferent activity from load receptors when the extensor muscles are unloaded in the late stance phase.¹⁶ If this unloading is prevented, the stance phase is prolonged. If we accept that the reflex pathway from pretibial muscle receptors to the knee extensor motoneurons is responsible for the load reaction of Q during stance phase, this plausible inhibition would be significantly important in initiation of the swing phase of gait where the lower limb should be unloaded. Hence, this precedence of activity in tibialis anterior and the strong presence of the reflex during the early stance phase may indicate a positive feed-forward effect from ankle flexor afferents to quadriceps.

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