Effect and length of the overflow principle in proprioceptive neuromuscular facilitation: electromyographic evidences

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ABSTRACT

Objective: To investigate the occurrence and irradiation/overflow amount on the muscular activity of healthy individuals submitted to proprioceptive neuromuscular technique

Design: Experimental study with convenience sample

Setting: Physiotherapy university rehabilitation centre.

Subjects: Sixteen volunteers dexterous, healthy (8 men and 8 women), with 18 to 24 years (21± 1.61) were evaluated.

Procedures: Bilateral electromyography of the upper limbs and trunk muscles (anterior deltoid, posterior deltoid, pectoral major and external oblique) were recorded during the proprioceptive neuromuscular facilitation exercise in left lower limb (diagonal of flexion/adduction/internal rotation). Electromyography were obtained in 5 conditions: (1) rest; (2) right upper limb concentric movement of extension-adduction-internal rotation; (3) left lower limb diagonal of flexion, adduction and internal rotation (4) left lower limb diagonal with contralateral upper limb having an attachment point; (5) right upper limb performing free diagonal 3, 6, and 9 seconds after irradiation technique.

Results: The lower limb isometric diagonal (condition 3) had the highest muscle activity of the posterior deltoid, external oblique (right side) and anterior deltoid, posterior deltoid, pectoral and external oblique (left side) compared to condition 2 (p<0.05). The exercise made with an attachment point (condition 4) was the most favorable to the majority of the muscles, followed by condition 3.

Conclusion: Based on the present data, irradiation technique is detectable in healthy subjects, considering the positioning to elicit muscle response at distance, ipsilateral and contralateral to the stimulus. Clinically, its use allows muscle contraction when there is some impediment in exercising a body segment directly.

Key-words: Electromyography, facilitation, physical therapy, skeletal muscle.

Introduction

Originally developed to facilitate performance in patients with neuromuscular disabilities¹, Proprioceptive neuromuscular facilitation (PNF) expanded to the several areas.² PNF propose to reach the highest functional level through facilitation, inhibition, reinforcement and relaxation of muscle groups³, increasing ability to move with coordination and synchronism. For such, procedures of the PNF as resistance, irradiation, reinforcement, a specific manual contact, verbal command, synchronization and facilitation patterns are used during specific techniques.⁴

PNF was already explored in different pathological conditions and with several objectives as stretching, endurance, flexibility.⁵,⁶,⁷,⁸,⁹,¹⁰ Only two studies, in 26 selected studies about PNF use, had approached overflow, calling it as crossed education.¹¹,¹² Hwang and Abraham (2001) had investigated synergies of the ankle and knee by
electromyographic records (EMG) of the anterior tibialis, rectus and biceps femoris muscles of 11 healthy subjects during isokinetic tests. There was overflow of the anterior tibialis muscle for the ipsilateral and contra lateral rectus femoris. Moreover, the EMG evoked through overflow was directly dependent of the angular speed of the exercised joint. Similarly, Shimura and Kasai (2002) compared EMG and evoked potentials of seven healthy subjects during movements initiated in neutral position versus PNF position. The findings had been favorable to the PNF proposals, since the electromyographic activity increased and the reaction time and the latency of the evoked potentials decreased.

The overflow or irradiation is defined as the propagation of synergetic muscle co-activations proceeding from a resisted movement. Such propagation could result in facilitation or inhibition during specific movements. In the facilitation sense, Adamson et al. (2008) suggested that the overflow migrates through the strongest muscle groups to the homologous muscles or any another body segment from proprioceptive inputs. Manual resistance is the most powerful and effective to produce overflow increasing the muscle recruitment and conscience of movement and strength. Of the biomechanical point of view, the overflow would be resulted of a body persecution to stability, having as consequence a broad variability of motor behaviors, according to individual conditions.

Few studies are devoted to overflow in comparison to the popularity of its use in the clinical practice. The majority of the scientific basis about overflow with the PNF has been produced about thirty years ago. In those studies, exercises made without resistance do not result overflow in healthy individuals. Pink (1981) submitted ten women to the PNF and verified increase of EMG in the non-exercised segment. It was not found predilection of activation to agonists or antagonistic muscles. The increase of EMG was understood as a stabilizing activity, mainly of the latissimus dorsi muscle. For hemiparetics condition, the overflow was observed after resisted exercises in the non-paretic side evoked EMG in the paretic side, but this is not observed in recently study. So, it is possible to note the importance to test and discover more about the overflow phenomena because of its clinical potential. The findings of such a study could contribute as an insight to the treatment of several injuries, in which, some part of body or even some muscles, are not possible to move or contract by themselves.

In the present study, it was tested the hypothesis that healthy subjects present electromyographic activity in unexercised upper limbs during the PNF irradiation technique applied in contralateral lower limb. Also, we hypothesized that contralateral upper limb muscle recruitment would be rise above free voluntary movement.

Therefore, the aim of this study was to investigate the occurrence and duration of the overflow from lower to upper limbs.

**Material and Methods**

The study involved a convenience sample with sixteen young volunteers subjects (8 men and 8 women), dexterous, healthy, age 18 to 24 years (21± 1.61). The healthy definition was an individual that no history of the musculoskeletal or neuromuscular diseases, no pain or other symptoms, which could affect of the motor control. As inclusion criteria, all subjects should be between 15 and 30 years and considered sedentary. Exclusion criteria were the presence of any orthopedic, cardiovascular, vestibular, psychiatric, neurological, and any other condition that would interfere in the results and/or not allow the execution of the technique. The research was analyzed and approved by the Ethics Committee in Research of Ribeirao Preto University (protocol number 044/05) and volunteers were informed about procedures used in the study and had signed informed consent forms.

**Equipment**

Delsys® electromyograph and bipolar electrodes of surface were used to record muscular activity (EMG). The electrodes were fixed bilaterally in right anterior deltoid (RAD), left anterior deltoid (LAD), right posterior deltoid (RPD), left posterior deltoid (LPD), right pectorals major (RPT), left pectorals major(LPT) and right external oblique (REO), left external oblique (LEO) muscles after trichotomy and cleanness procedures according to SENIAM (Surface ElectroMyoGraphy will be the Non-Invasive Assessment of Muscles) protocol from the Biomedical Health and Research Program (BIOMED II) of the European Union. Also, an electrode of reference was fixed in the lateral region of the trunk (left side, next to the last ribs). Data collection time was of 3 seconds and the sampling frequency was of 1000 Hz.

**Procedures and Data acquisition**

EMG activity was recorded bilaterally in supine position and the left lower limb was supported with 90° of hip and knee flexion, 10° of internal rotation of hip. Goniometric measurement was carried before and after each EMG record to guarantee the maintenance of the described position. Electromyography records were collected in the following conditions:

- 1- rest (upper limbs in neutral position).
- 2- right upper limb free diagonal (extension - adduction - internal rotation - with extension of elbow).
• 3 - left lower limb isometric diagonal (flexion - adduction - external rotation) while upper limb rests in flexion, abduction and external rotation.

• 4 - left lower limb isometric diagonal while right upper limb having a point of attachment (the participant holds edge of the stretcher adopting the starting position of the upper limb PNF pattern to make extension - adduction - internal rotation).

• 5 (a, b and c) - upper limb free diagonal of the right upper limb (extension – adduction - internal rotation - with extension of elbow) 3 (a), 6 (b) and 9 seconds (c) after the left lower limb isometric PNF diagonal (flexion - adduction - external rotation).

To consider the PNF concepts, conditions 3, 4 and 5 were composed by isometric contractions as the participant movements were blocked by manual resistance. Also, a rest of one minute after all the conditions and 30 seconds between trials were used to prevent interference.

Data Analysis and Statistical Analysis

EMG signals were expressed in millivolts (mV) and normalized by the maximum voluntary contraction (MVC). The Root Mean Square (RMS) of each muscle was used for analysis of the data. For the statistics analysis it was used Statistics software (version 5.0). The Wilcoxon matched pairs test was used to compare the different conditions of trials (p<0.05).

Results

The median values of the RMS and the quartiles (25%-75%) of EMG monitored in different conditions are shown in Table 1.

The condition 2 presented larger EMG activity of the RAD, RPD, RPT and LPT (p<0.05) compared to condition 1, while the others muscles presented similar EMG activity (p>0.097). The condition 3 revealed larger EMG activity of the muscles RPD, REO, LAD, LPD, LPT and LEO (p<0.05) compared to condition 2, and the others muscles were similar (p=0.147).

The condition 4 showed the highest EMG activity of the muscles REO and LEO, but lower EMG activity of the muscles RPT, LAD and LPD (p<0.05) compared to the condition 2, while others muscles presented similar EMG activity (p>0.108).

The condition 5a, presented larger EMG activity just to REO muscle (p<0.05) compared to condition 2, while the others muscles were similar (p=0.325).

The condition 5b revealed larger EMG activity for RAD and RPD muscles and lower EMG activity of the RPT and LEO muscles compared the condition 5a (p<0.05), and the others muscles were similar (p>0.078). Finally, all muscles of the condition 5c were similar to condition 5a (p=0.062).

Discussion

Our results support the initial hypothesis since the overflow was observed during the diagonal of PNF even in healthy subjects of the present sample. The aim of the study was also reached, as we showed the occurrence of overflow, specially and more intense when the upper limb perform the free diagonal at the same time of the isometric contraction of lower limb (condition 3) and also when the upper limb had a point of attachment during isometric contraction of lower limb (condition 4) for REO and LEO muscles. About the duration of the overflow effect a surprise result was found: after 3 seconds of the isometric contraction of lower limb, REO increased its activity. Also RAD and RPD, increased their activities, comparing 3 to 6 seconds, after the isometric contraction be done. So, although little, it seems that exist a residual effect of the overflow phenomena that disappears between 6 and 9 seconds.

Overflow was one of less described techniques of PNF with specific scientific evidences. The approach of Pink (1981) was different of the present study because its investigation focused overflow in upper limbs instead upper and lower limbs. With respect to the adopted method, similarities are found in the tool of recording (EMG) and the test position (supine). The chosen diagonal patterns differ, as well as the muscles monitored. However, the results point in same direction: the overflow of the EMG activity to non-exercised segments. The increased EMG was registered in the conditions whose irradiation technique was applied (3 and 4). Moreover, the comparison between the studied conditions had identified that the recruitment during the irradiation technique (conditions 3 and 4) also surpasses free voluntary movement (condition 2). Data obtained in condition 2 serves as a baseline for the EMG of the right upper limb during the extension-adduction-internal rotation pattern. Its comparison with the rest was useful to confirm the muscles of the upper limb involved in the diagonal in supine position. The conventional use of PNF adopting concentric patterns does not mention RAD recruitment during the diagonal extension -adduction -internal rotation. However, it is reasonable that RAD activity has occurred in the position adopted (deceleration during the shoulder extension in favor to the gravity). Considering the condition applied in the study and the limited number of muscles monitored, there was a preferential facilitation to the contralateral upper limb (RAD, RPD, RPT, REO) during condition 3, but also a bilateral facilitation during condition 4. Clinically, as cited for Pink (1981) it is an interesting finding so the physiotherapist can induce
muscular contractions at distance when there are some impediment in exercising a body segment.  

The comparison of conditions 2 and 4 allowed inferring which the magnitude of the recruitment in the upper limb during the diagonal of extension - adduction - internal rotation and another diagonal executed by lower limb. EMG activity for REO and LEO in condition 4 was higher than condition 2. These data also point an excellent condition to promote muscle activation at distance. Comparisons between condition 2 and 3 had presented similar results, reinforcing the hypothesis of the overflow existence. Further than the gap of scientific evidences about overflow, this study clarified the application form to get it. If the participant adopts one given position and has a point of attachment, as in the condition 4, higher muscular activity occurs at distance.

### Underling mechanisms to the overflow

**Neural Mechanisms:**

There is no consensus about the mechanisms that promote the overflow/irradiation. A hypothesis would be of neural and central resource. Kristeva et al (1991) evidenced that unilateral voluntary movement also involved contra lateral cortical activity.  

Similarly, Carrol et al (2006) attributed contralateral effects to the post-training adaptations in the nervous system.  

In general way, supraspinal changes in motricity demand continued exposition to certain stimulations to trigger motor learning.

### Table 1. Median and quartiles (25%-75%) for all muscles in the different conditions.

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<tbody>
<tr>
<td>RAD</td>
<td>0.04 (0.02-0.08)</td>
<td>0.15 (0.08-0.13)</td>
<td>0.19 (0.14-0.24)</td>
<td>0.08 (0.05-0.13)</td>
<td>0.14 (0.12-0.23)</td>
<td>0.18 (0.14-0.28)</td>
<td>0.18 (0.17-0.31)</td>
<td>0.001</td>
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<tr>
<td>RPO</td>
<td>0.05 (0.02-0.07)</td>
<td>0.06 (0.03-0.11)</td>
<td>0.07 (0.06-0.13)</td>
<td>0.05 (0.03-0.13)</td>
<td>0.07 (0.03-0.08)</td>
<td>0.10 (0.04-0.14)</td>
<td>0.09 (0.03-0.24)</td>
<td>0.034</td>
</tr>
<tr>
<td>RPT</td>
<td>0.15 (0.10-0.28)</td>
<td>0.78 (0.47-1.45)</td>
<td>0.95 (0.63-1.28)</td>
<td>0.24 (0.15-0.46)</td>
<td>0.77 (0.52-1.39)</td>
<td>0.60 (0.44-1.21)</td>
<td>0.63 (0.43-1.20)</td>
<td>0.000</td>
</tr>
<tr>
<td>REO</td>
<td>0.41 (0.19-0.75)</td>
<td>0.43 (0.21-0.76)</td>
<td>0.83 (0.48-1.07)</td>
<td>0.90 (0.57-1.14)</td>
<td>0.42 (0.18-0.66)</td>
<td>0.41 (0.19-0.61)</td>
<td>0.42 (0.19-0.60)</td>
<td>0.958</td>
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<tr>
<td>LAD</td>
<td>0.03 (0.03-0.06)</td>
<td>0.04 (0.03-0.06)</td>
<td>0.07 (0.04-0.14)</td>
<td>0.06 (0.04-0.11)</td>
<td>0.04 (0.03-0.07)</td>
<td>0.04 (0.02-0.04)</td>
<td>0.04 (0.03-0.06)</td>
<td>0.112</td>
</tr>
<tr>
<td>LDO</td>
<td>0.04 (0.02-0.07)</td>
<td>0.04 (0.03-0.09)</td>
<td>0.41 (0.15-1.24)</td>
<td>0.29 (0.15-0.85)</td>
<td>0.04 (0.02-0.08)</td>
<td>0.06 (0.03-0.09)</td>
<td>0.04 (0.03-0.07)</td>
<td>0.298</td>
</tr>
<tr>
<td>LPT</td>
<td>0.10 (0.08-0.22)</td>
<td>0.13 (0.09-0.29)</td>
<td>0.29 (0.16-0.36)</td>
<td>0.22 (0.10-0.32)</td>
<td>0.19 (0.11-0.31)</td>
<td>0.11 (0.07-0.26)</td>
<td>0.11 (0.08-0.28)</td>
<td>0.001</td>
</tr>
<tr>
<td>LEO</td>
<td>0.31 (0.17-0.57)</td>
<td>0.39 (0.20-0.56)</td>
<td>1.07 (0.88-1.81)</td>
<td>0.76 (0.68-1.57)</td>
<td>0.41 (0.29-0.66)</td>
<td>0.30 (0.22-0.51)</td>
<td>0.38 (0.19-0.54)</td>
<td>0.097</td>
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Comparisons:  † 1 x 2; ‡ 2 x 4; ¶ 2 x 3;  * 2 x 5a;  † 5a x 5b; † 5a x 5c; †= p<0.05.
It remains another phenomenon of neural and biomechanical nature, capable to promote faster adaptations.

In a recent review, Carrol et al (2006) also approach the contra lateral effects of unilateral force trainings and raise the possible neural mechanisms involved, in which "spillover", that is, overflow is applicable for our results.21

Tracing a parallel to crossed-training effect studies, in which there are evidences of contralateral reinforcement in the absence of movement,22 it is reasonable that PNF modifies the neural excitability. Facilitation could occur due to reduced co-activation of the antagonist and this could be registered by needle electrodes.23 Also, it could occurred facilitation due an increased motor units synchronization discharges.24 The only study that verified spinal excitability after 5 weeks of isometric contralateral training failed to find changes in the H reflex amplitude.25 Thus, the spinal reflexes contribution on the contra lateral strengthening to a trained limb seems remote. Although, Lagerquist Zehr and Docherty (2006) suggest supraspinal mechanisms26 and the overflow as a product of inter-hemispheric disinhibition, for example in hemiparetic.27 However, surpassing correlation from our overflow/irradiation data to these electrophysiological studies is speculation.

Reasonable explanation for the irradiation could be related to the corticospinal tract anatomy. In animals, approximately 10% of the corticospinal fibers descend ipsilaterally.27 Thus, with a verbal command and manual resistance during PNF pattern, contralateral and homolateral alpha motoneurons would be activated. Given the disproportionately bigger of the corticospinal tract bilateral projections for motoneurons for the proximal muscles,25,29,30 its activation also would be obtained. Without inhibitory circuits28 or inter-hemispheric connections,22,32,33,34,35,36 activation of the exercised segment and of homologous muscles would take place. Such efficient inhibition could result in fewer overflows, considering neurologically intact individuals. Replicating our study with neurologically injured participants could be useful to clarify this question.

The data of the present study, as well as those presented by Pink (1980)16 suggest that the overflow are not restricted to the homologous muscles. So, another factors of biomechanics resource must be contribute for the registered muscular activation.

**Biomechanical factors**

In the majority of the tested conditions, obliquous muscle was active. The PNF pattern used in our study involves flexion, adduction, external rotation, knee flexion and dorsiflexion. The most powerful muscle of this pattern is psoas iliac2,3 and its contraction has repercussion on the other segments, particularly the lumbar spine. With origin in the vertebrae bodies of the twelfth until the fifth lumbar vertebrae and insertion on the vertex of minor trochanter of femur, psoas iliac has a powerful action on the lumbar spine, eliciting lumbar hyperlordosis and pelvis anteverision in the dorsal decubitus. To counterbalance such action, abdominal muscles activation stabilizes the trunk.

Axial stability managed by the central nervous system implies in abdominis, oblique and multifidus contraction. According to Kumar et al (2002) the superficial layer of external obliques muscle, analyzed in our study, initiates and keeps axial rotation associated by trunk flexion to the contra lateral lower limb direction.27 Then, this explains the increased activity of oblique muscles during the PNF in lower limb (conditions 3 and 4). Increased EMG in the non-exercised segment (upper limb) seems to be to keep body stability (condition 3). The RPD activity is increased when the trunk rotation occurs ipsilateral to the movement, reflecting co activation.28 Such co activation already would be the effect of the overflow caused by lower limb isometric contraction, as synergic and stabilizing action.

**How long lasts the effect of the overflow?**

Another question without definition is the time effect of the irradiation. Although this technique does not result in tremendous levels of muscle activity in healthy individuals, our results showed that just RE0 presented larger EMG activity at 3 seconds (condition 5a), but at 6 seconds (condition 5b) showed that ipsilateral muscles were more active. This suggests that between 3 and 6 seconds could be a residual effect of the overflow. Nevertheless, it is possible that the EMG variability could be lead for this result. It is important to mention that some pathological conditions promote impaired neuromuscular control and different behaviour of the irradiation could occur. Future studies could explore the effectiveness of the technique over different diseases, and verify if protocols of training with overflow are capable to precipitate peripheral adaptations as strengthening. The point of prominence of this study is the increase of the muscle activity ipsilateral and contra lateral to the segment that worked in isometric form in healthy individuals.

**Conclusion**

Based on the present results, the irradiation technique is detectable, considering the desirable interferences of the positioning to elicit muscle responses at distance, ipsilateral and contralateral to the stimulus. We found overflow mainly during the execution of condition 3 (lower limb isometric diagonal (flexion - adduction -
external rotation) while upper limb rests in flexion, abduction and external rotation) and condition 4 (left lower limb isometric diagonal while right upper limb having a point of attachment, maintaining the member in flexion, abduction and external rotation). Clinically, it can be used to facilitate muscle contraction when there is some impediment in exercising a body segment.

Acknowledgments
The authors wish to thank all volunteers involved in this study and Gil Lucio Almeida, PhD for support of the laboratory equipments.

Conflict of Interest
The authors declare that there is no conflict of interest.

References


