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Original research study

Immediate effect of common peroneal nerve electrical stimulation on quadriceps muscle arthrogenic inhibition in patients with knee osteoarthritis

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A R T I C L E I N F O

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A B S T R A C T

Objective: To investigate the immediate effect of electrical stimulation of the common peroneal nerve on the maximum voluntary activation of the quadriceps muscle in patients with knee osteoarthritis.
Methodology: Fifteen subjects with knee osteoarthritis (mean age: 50.5 ± 13 years) participated in this study. To measure the arthrogenic inhibition ratio of quadriceps, a burst of electrical stimulation was superimposed on the maximum voluntary contraction, and the percentage of change in the force production was computed. The same measurement was also performed with concurrent electrical stimulation of the common peroneal nerve.
Results: All the patients with knee osteoarthritis showed significant arthrogenic inhibition of the quadriceps muscle. The stimulation of the common peroneal nerve was able to reduce this inhibition and increase the capacity of the muscle to produce a significantly higher knee extension force ($p = 0.028$).
Conclusions: Electrical stimulation of the common peroneal nerve concurrent with the maximum voluntary effort can remove the arthrogenic inhibition of the quadriceps muscle in patients with knee osteoarthritis. This finding could have clinical implications in the management of patients with knee disorders.

1. Introduction

In 1978, Bergman's group (1978) described an excitatory reflexive response in the quadriceps muscle motor neurons that was generated by electrical stimulation of the common peroneal nerve (CPN). This reflex, introduced as an oligosynaptic reflex, is transmitted to the quadriceps alpha motoneurons through the activation of group I and II pretibial muscle receptors.

Hence, identifying the characteristics of this excitatory reflex between the pretibial and quadriceps muscles can help in understanding the nature of many sensorimotor disorders. Proprioceptive inputs can produce significant changes in excitatory reflexes between the pretibial and quadriceps muscles, so that as we get closer to the end range of knee extension or hip joint flexion, the reflex strength is increased such that the maximum strength and efficiency of the reflex is observed in the last 15° of the knee extension and hip flexion (Kalantari and Baxendale, 2007). Indeed, the changes in this reflex through various sensory pathways can influence the motor control of knee extensors during functional activities such as walking. The change in the pattern of this reflex during walking also reflects its important role in the control of lower limb function during stance and the start of the swing phase of gait (Kalantari and Baxendale, 2009). The weakness of this reflex during the stance phase can lead to instability of the knee joint. On the other hand, excessive reflex expression can cause problems during unloading and the start of the swing phase (Kalantari et al., 2001).

The activation of this excitatory reflex between the pretibial and

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quadriceps muscles is only observed during voluntary contraction of the quadriceps muscle, and is directly related to the intensity of contraction. Thus, with an increase in the voluntary effort of the quadriceps muscle, the excitatory effect of this reflex also increases so that this reflex is inactive at rest (Kalantari and Baxendale, 2007). Changes in the activation pattern of this reflex have been reported in neurological diseases, and intensified reflexes have been observed in patients with hemiplegia or Parkinson's disease (Maupas et al., 2004; Simonetta et al., 2002).

Arthrogenic muscle inhibition (AMI) is defined as the inability of the patient to maximally contract a muscle. AMI of the muscles surrounding the affected joint is inevitable in patients with different knee disorders including knee osteoarthritis (Hopkins and Ingersoll, 2000).

Muscle inhibition is a barrier against effective rehabilitation interventions for knee joint dysfunction resulting from different traumatic and non-traumatic injuries including osteoarthritis. Quadriceps muscular inhibition following injuries to the knee joint leads to muscle atrophy and prevents maximum activation of the quadriceps muscle, which is largely responsible for the weakness of this muscle (Hurley et al., 1994; Keays et al., 2000). This inhibition delays or prevents the strengthening of the quadriceps muscle, and despite resistance training, the quadriceps strength may remain unchanged or even decline significantly (Keays et al., 2003; Rossi et al., 2005; 2002), an effect attributed to AMI (Stevens et al., 2003). This inhibition is stronger in the first few months after an injury, or in cases where the injury is severe. In such cases, muscle strengthening protocols are often ineffective. Despite the fact that muscle inhibition decreases over time following an injury, it is clear that this inhibition can persist for months and even years after the injury. Persistent quadriceps weakness is clinically important as it may impair dynamic knee stability (Keays et al., 2003), physical function, and quality of life (Yoshida et al., 2008), and may increase the risk of re-injury to the knee joint (Stokes and Young, 1984) and contribute to the development and progression of osteoarthritis (Brandt et al., 2008; Mikesky et al., 2006; Slemenda et al., 1998). Thus, any intervention that can decrease or remove the AMI has an important impact on the prognosis of rehabilitation programs in these patients (Hopkins and Ingersoll, 2000). As such, considering the nature of this excitatory reflex between the pretibial and quadriceps muscles, we can expect a positive effect of this reflex in removing the arthrogenic inhibition of the quadriceps.

Force-based measures of quadriceps activation have been widely used to determine the proportion of the quadriceps motor neuron pool that can be volitionally activated. The superimposed burst technique uses a supramaximal, percutaneous electric stimulation during a maximal, voluntary isometric knee extension contraction to calculate the central activation or arthrogenic inhibition ratio. In theory, if an individual is able to contract all motor units in the quadriceps, electric stimulation will not cause any increase in force (Palmieri et al., 2004). Similarly, if a portion of the quadriceps is inhibited, external stimulation will cause a force-producing contraction that is greater than the volitional contraction, regardless of the measurement technique used.

In this study, we investigated the immediate effect of electrical stimulation of the common peroneal nerve on the arthrogenic inhibition of the quadriceps in patients with knee osteoarthritis.

2. Materials and methods

2.1. Participants

In this non-experimental study, 15 subjects (9 men, 6 women) with knee osteoarthritis were recruited by simple non-probability and convenience sampling methods. The subjects included patients with unilateral knee osteoarthritis grades 2 and 3 (9 right knee and 6 left knee), graded according to the Kellgren and Lawrence scale, who were referred to the physiotherapy clinic of the Shahid Beheshti University of Medical Sciences in 2015. The Kellgren and Lawrence system that was accepted by the World Health Organization (WHO) in 1961, is a method of classifying the severity of knee osteoarthritis (OA) using the following five grades:

- Grade 0: no radiographic features of OA are present
- Grade 1: doubtful joint space narrowing (JSN) and possible osteophyte formation
- Grade 2: definite osteophytes and possible JSN on a weight-bearing radiograph
- Grade 3: multiple osteophytes, definite JSN, sclerosis, possible bony deformity
- Grade 4: large osteophytes, marked JSN, severe sclerosis, and definite bony deformity

The demographic information of the participants including their height, weight, body mass index (BMI), and age are included in Table 1.

The inclusion/exclusion criteria were as follows:

Inclusion criteria:
- Lack of any musculoskeletal or neuromuscular abnormality that limits the range of motion of the lower limbs
- No history of balance disorder or neurological disease
- Osteoarthritis grade 2/3 based on the Kallgren and Lawrence scale

Exclusion criteria:
- Use of any particular medicine during the course of the study
- The study was approved by local ethical committee and the patients signed an informed consent form prior to participation in the study.

2.2. Study design

The patients were asked to sit on a specific chair with an adjustable arm that was designed for this study (Fig. 1). The arm of the chair had 3 degrees of freedom, and was adjusted in different positions so that its pressure pad could be adjusted in the proper position against the patient's leg. An electrical dynamometer was mounted inside the pressure pad to measure the force exerted by the patients. The subjects' thigh and back were fixed by a strap, so that proper positions of the knee and hip were achieved. In a primary study, the reliability of the measurements made using the designed chair and the installed dynamometer was evaluated on 15 healthy young adults. The result showed a very good reliability for the maximum isometric force with an intraclass correlation coefficient (ICC) greater than 0.90. To achieve the maximum reflex effect, the knee joint was positioned at 15° of flexion and the hip was positioned at 80° of flexion.

To warm up, the subject performed submaximal isometric contractions against the pressure pad with a self-selected force, and

Table 1
Demographic information of the participants (15 Patients).

Variables	Criterion			
	Mean	SD	Min	Max
Age (year)	53	13	35	73
Height (cm)	175	12	164	188
Weight (kg)	81	7	64	96
BMI	26	3	22	30

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