Artificial Organs
26(3):260–262, Blackwell Publishing, Inc.

Dermatome Electrical Stimulation as a Therapeutic Ambulatory Aid for Incomplete Spinal Cord Injured Patients

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Abstract: Electrical stimulation of the L-3,4 dermatome during treadmill walking is proposed as a gait training modality in incomplete spinal cord injured patients. The dermatome stimulation proved to be efficient in diminishing the extensor tone occuring after loading of the paralyzed limb during the stance phase of walking and resulting in improved flexion of the leg during the swing phase. **Key Words:** Dermatome—Electrical—Stimulation—Therapy—Incomplete—Spinal cord injury—Treadmill.

In the last decades more incomplete than complete spinal cord injured (SCI) patients are arriving in the spinal units. One of the primary goals of the rehabilitative program for the incompletely paralyzed subjects is not only returning them to standing position but also restoring their walking patterns. There are several gait training modalities available for this group of patients. In Table 1 they are divided into the methods based on mechanical activation or electrical stimulation of the partially paralyzed lower extremities. Some of these approaches are provoking passive movement of the leg while others are eliciting reflex responses.

It is our belief that the approaches that are providing merely the movement of the leg are less efficient in relearning of walking. Robot manipulators combined with treadmills are used to lift the leg and bring the foot forward. In this case only the afferent input from the joint receptors may promote the gait relearning process. Similar movements can be accomplished by active exoskeleton systems. Gait pattern can be restored in paralyzed persons also by surface or percutaneous multichannel electrical stimulation. Strong electrical stimuli delivered to the efferent nerves may represent unwanted noise in the afferent nerves, thus hindering the relearning process.

The gait training modalities eliciting reflex responses result in more complex and natural-like movements that are provoking afferent signals in joints, tendons, and muscles. Treadmills produce hip extension at the end of the stance phase, which is inducing reflex hip flexion and thus initiating the swing phase of walking (1). A powerful motor and gear system attached to a mechanical ankle joint orthosis by means of flexible bowden cables can elicit stretch reflexes by displacing rapidly the ankle joint (2). Vibration of muscles and tendons activates muscle spindle afferents and produces illusory changes in joint position (3). Illusion of the altered position may play an important role in gait training. It was demonstrated already in 1973 (4) that electri-

TABLE 1. *Gait training in partially paralyzed patients*

Providing movement of leg	Eliciting reflex response
Mechanical activation	Mechanical activation
Robot manipulators	Treadmill
Active exoskeletons	Active joint orthosis
	Tendon vibration
Electrical stimulation	Electrical stimulation
Multichannel surface	Afferent nerve
Multichannel percutaneous	Spinal cord
	Dermatome

Received October 2001.
Presented in part at the Seventh Vienna International Workshop on Functional Electrical Stimulation, held September 12–15, 2001, in Vienna, Austria.
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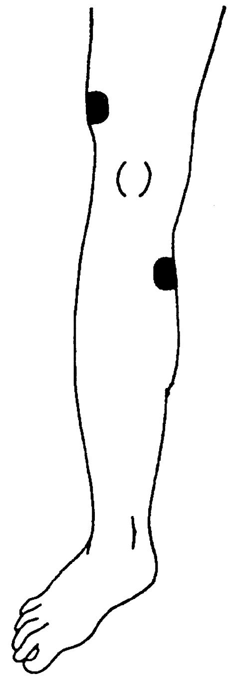

FIG. 1. The drawing shows positions of the surface electrodes over the L-3,4 dermatome.

cal pulses applied to the sural or tibial nerves result in reflex hip and knee flexion with a simultaneous reflex ankle dorsiflexion. The swing phase obtained by eliciting a synergistic flexion response through electrical stimulation of the common peroneal nerve was extensively used by our group (5). The spinal cord stimulation has a predominantly afferent influence (6). Due to this stimulation, the supraspinal structures exert their influence through the descending pathways and segmental reflexes, and thus at least partially restore the brain control over the locomotor system. In this article, we are proposing the dermatome stimulation combined with treadmill walking as a modality for gait training in incomplete SCI persons (7).

MATERIALS AND METHODS

The swing phase of walking can be influenced through cutaneous stimulation of the selected dermatomes. In the investigation, a 63-year-old patient with a C 2–6 spinal cord lesion resulting from an accident was selected. The electrodes were placed over the L-3,4 dermatome, 1 medially below the knee and the other laterally above it, with the aim to decrease the extensor spasticity of the knee extensors, innervated from the same spinal cord level as the dermatome. Schematic representation of electrodes positioning is shown in Fig. 1. A stimulation frequency of 100 Hz and a pulse duration of 0.3 ms were used without interruption during the gait cycles. The electrical stimulation was not causing any muscle contraction. It is our belief that the sensory electrical stimulation was delivered predominantly through the large diameter afferent fibers.

RESULTS

Strong extensor spasticity is often observed in the lower extremities of the incomplete SCI patients. Af-

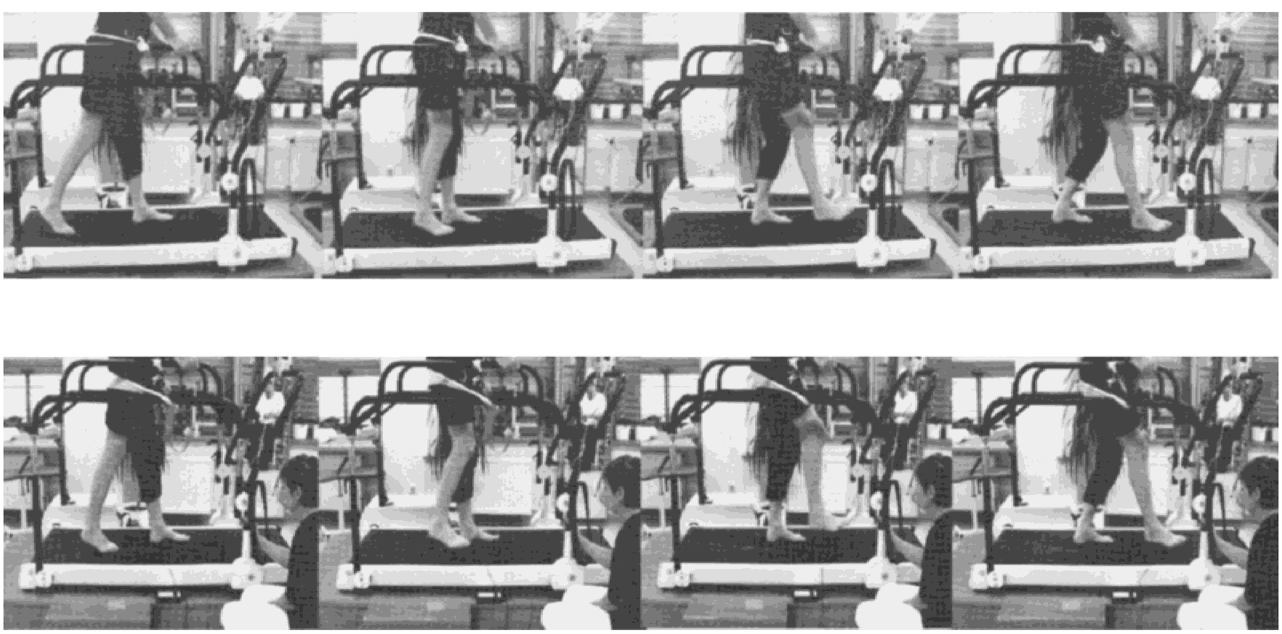

FIG. 2. The photographs are a record of an incomplete SCI patient's walking without (**upper row**) and with the dermatome electrical stimulation (**lower row**).

ter loading the paralyzed limb during the stance phase of walking, the patients have difficulty breaking this extension tone and cannot initiate a step. The stimulation of the L-3,4 dermatome proved to be efficient in diminishing this extensor activity. Hip and knee flexion and ankle dorsiflexion were significantly increased during the swing phase of walking. Also, the eversion of the foot was noticeably improved when delivering the dermatome stimulation. The upper series of photographs in Fig. 2 show walking without stimulation. The lower photographs show an improved swing phase of walking during L-3,4 dermatome stimulation. The dermatome stimulation proved to be efficient especially when combined with treadmill walking.

DISCUSSION

Despite several decades of investigations of functional electrical stimulation (FES) for lower extremities, we cannot claim that FES of lower limbs is used widely in the clinical environment. The FES synthesis of walking requires complex multijoint movements that further require a large number of surface or implanted electrodes together with special algorithms providing coordination of many channels of electrical stimulation. It is our belief that only simple FES systems are promising from the clinical point of view. Electrical stimulation of spinal neural circuits, rather than direct activation of motoneurons, will simplify generation of complex motor behaviors (8). Electrical stimulation of the dermatomes, described in this article, is just one possible access to the spinal neural circuitry from the periphery.

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