SENSORY-MOTOR POSTURE CONTROL IN LUMBAR DISORDERS

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Summary

The neuromuscular control system (NCS) is endlessly challenged. Perturbations of a subsystem of NCS can usually be compensated by another subsystem, but the NCS may fail at a certain point of stress. The compensation capacity of NCS may be reduced also in musculoskeletal disorders, allowing musculoskeletal structures to become vulnerable to continuing or repeatable stress. Impairments in motor and sensory functions have been associated with numerous musculoskeletal disorders. These impairments include disturbances in a wide range of sensory-motor control, e.g. sensory dysfunctions, motor

deficiencies, impaired postural responses, psychomotor control and motor learning. However, the physiological mechanisms, clinical relevance and characteristics of these findings are still under debate. In addition, the motor and sensory changes are greatly dependent on the pathophysiology and clinical stage of the disorder. Clearly impaired lumbar sensory and motor functions are associated with LBP, but especially with LBP due to clear pathomorphological findings. The pure reflex activation of muscles may not be primarily affected but a difference could be found in the premotoneuronal response control. The impaired proprioceptive functions, premotoneuronal response control and muscle endurance seems to be reversible, at least to certain extent, after successful treatment. However, the complex activity of maintenance of postural stability does not seem to recover automatically.

1. Introduction

Performance of all active movements and maintenance of postural stability are controlled by the neuromuscular system. The force produced by the muscles has to exceed the gravity—at least on the Earth. Movement and posture control are essential for life, and they are one of the most primitive physiological functions. Disorders of motor control can have dramatic effects. Falling down can endanger life, even indoors at home.

The relevance of neuromuscular control in every day life and in certain bone and joint/musculo-skeletal disorders are reviewed in this article, with a special emphasis on trunk muscle function and postural control in low back pain (LBP). Some basic knowledge about postural and movement control is also presented.

The appropriate muscular control and movement, as well as posture perception are of vital importance in preventing low back injury. The protection against injury requires anticipation of events and adequate muscular responses. Both abnormal and missing protective reflexes could possibly lead to trauma or microtrauma of muscles, nerves, intervertebral discs and ligamentous spine during loading. The impaired movement control is often observed in lumbar spinal disorders. There is increasing evidence that these functions can be recovered by treatment and restored by active rehabilitation.

Pain is defined as an unpleasant sensation and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Acute pain usually eases during tissue healing or after the impending threat of tissue damage has passed. In conditions of chronic neuropathic pain, the sensory processing of the affected body region becomes abnormal and there may become detectable changes in central information processing and altered pain experience.

Low back pain is defined as pain in the lumbar area. It is a common problem, which affects the majority of the population. The lifetime prevalence of LBP varies from 60 to 90% with an annual incidence of approximately 5%. In many cases, back problems tend to show the first symptoms before the age of twenty. Usually the pain is acute and improves in less than two months, but most of these cases will experience relapses with each episode becoming worse and worse, the pain being a recurrent continuum.

Approximately 5 to 10% of cases become chronic, lasting over two months and creating a major medical challenge.

Low back pain is the most common musculo-skeletal disorder causing huge humanitarian and economic costs. The pain may arise from injured structures within the lumbar back. The anatomical cause and functional consequences of the syndrome often remain, however, undefined. In chronic pain, the precise etiology is even less well understood. Imaging studies such as magnetic resonance imaging (MRI) visualize the macroscopic structural changes but similar changes are often found in subjectively healthy subjects and frequently the correlation with the clinical condition seems to be rather low. Furthermore, LBP is not just a bone and joint disease but also a neuromuscular disorder. The chronic LBP is a multidimensional problem including pain and functional disability with its associated psychic and socioeconomic consequences. Impairments in neuromuscular control have often been associated with chronic LBP and are considered a probable link between pain and disability. Thus, the impaired neuromuscular control becomes particularly emphasized in conditions of chronic pain, which are also the most expensive for society and the most demanding for the health care system.

Nerve-root symptoms occur only in a small percentage of acute LBP patients, but they are often associated with enduring and persistent pain. Sciatica is defined as pain in a distribution of a lumbar nerve root, often accompanied by sensory and motor deficits. Sciatic pain requires that there are mechanical and inflammatory stimuli to lumbar nerve roots. The most common cause of sciatica is a herniated lumbar disc, but in the ageing population, there is now an increased prevalence of lumbar spinal stenosis (LSS) as a cause of sciatica.

Low back pain syndrome can be defined as a multidimensional problem including pain, functional disability and socio-economic consequences. The LBP syndrome seems to be a continuous process, and the functional disorders vary with respect to the stage and duration of the illness and physical and psychological stress. However, the time course of the LBP and the relation between time and symptoms are poorly understood. According to experimental studies, the spatial or temporal overloading of spinal structures leads to micro-injuries, inflammation, pain and neuromuscular dysfunction. This dysfunction has been claimed to be associated with clinical syndrome.

2. Motor Control

The central nervous system (CNS) controls all movements and posture by the function of the muscles, which are performing the work. The commands for muscular activation are programmed in CNS and transmitted through peripheral nerves. The motor commands initiating voluntary movements are mediated by corticospinal pathways. The major descending pathways controlling body posture are vestibulospinal tracts. The neurons of vestibulospinal tracts synapse with the same alpha motor neuron as the corticospinal tract.

Human motor control can be divided schematically into three different co-operating levels (see Figure 1). The highest level is planning of the movement, the lowest level is spinal reflexes and the intermediate level connects the highest and lowest levels for the execution of the task. The terms voluntary and reflex are widely used in scientific papers and in everyday conversation, but the exact meaning of these terms is not clear and need some definition. Isolated voluntary and automatic actions are rarely seen in real life. The normal functions are combinations of different levels of control. Reflexes assist in voluntary functions and cortically controlled activation may regulate reflexes. The primary motor cortex is involved in reflex inhibition via the descending pathways, which vary their activity level according to the attention, arousal and emotional state of the subject.

2.1. Focused Attention

2.1.1 Voluntary Control of Movements

Voluntary movements are programmed in the brain. Several cortical areas, e.g. supplementary motor cortex, basal ganglia, cerebellum, thalamus, anterior gyrus cinguli and primary and supplementary somatosensory cortex, are linked to the primary motor cortex. These centres are involved in the planning of the movement. The final command to perform the motion is initiated by the pyramidal cells of the primary motor cortex and transmitted through the corticospinal pathway to the ventral horn of the spinal cord. At a specific spinal level, the upper motor neuron synapses with the alpha (lower) motor neuron which then transmits the command to muscle fibres of its own motor unit.

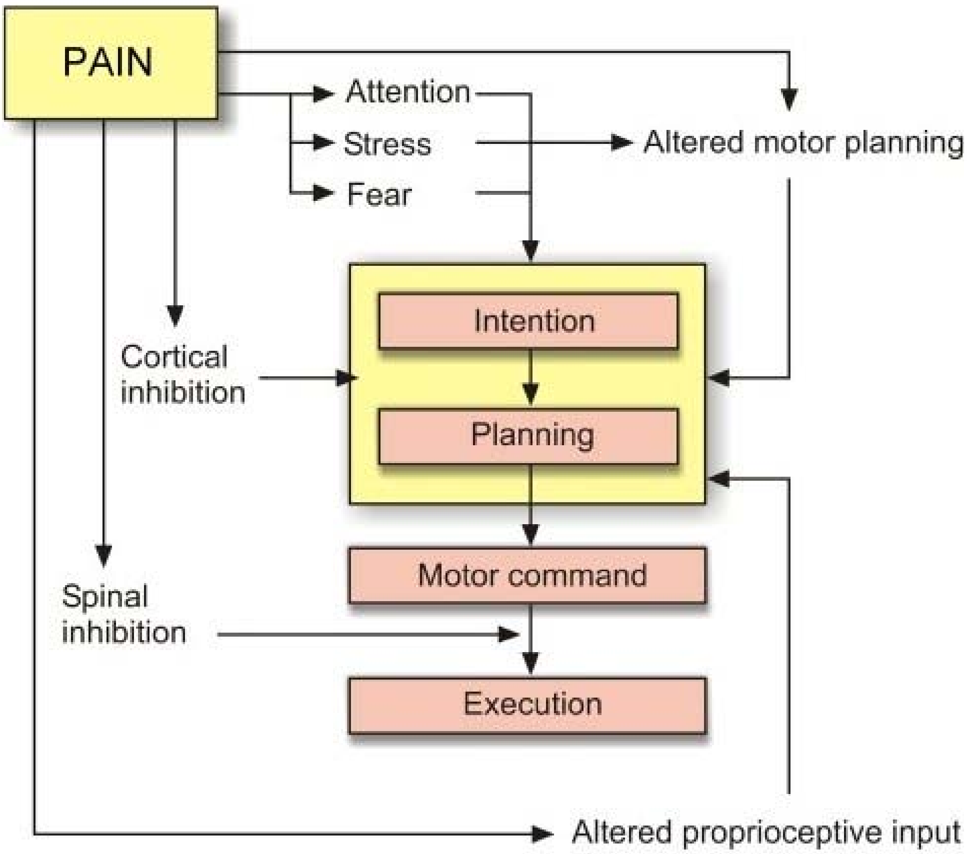

Figure 1. Potential mechanisms for the effect of pain on motor control

2.2. Subsidiary Movements

Subsidiary muscle activations are often associated with voluntary movements. They are servo actions needed, for example, in postural control. These movements include anticipatory postural adjustments and triggered reactions. The subsidiary actions are usually automatic, i.e. unconsciously controlled, but they are more complex than simple reflexes. The responsible level controlling these rapid actions is thought to be intermediate; it is also called the extrapyramidal system. This includes the thalamus, basal nerve nuclei, basal ganglia and cerebellum. These are involved also in the tuning of fine movements, coordination, timing, motor learning and muscle tone.

2.2.1. Anticipatory Movements

In predictable postural perturbation, the CNS can plan control strategies in advance. According to the recognition schema theory, muscle activation can be pre-programmed based on initial condition, environmental outcome and expected sensory consequences. Voluntary upper or lower limb movements evoke non-conscious muscle activation in trunk and lower limb muscles via a feed-forward mechanism.

In feed-forward activation, certain trunk muscles are activated before the activation of the prime muscles responsible for the gross limb movement without an afferent input from the respective trunk movement. The anticipatory postural adjustments are essential for maintenance of postural stability during voluntary movements.

2.2.2 Automatic Motor Programs

Reflexes are the fastest way to control movements. They are categorically divided into mono-, di- and polysynaptic reflexes. The monosynaptic reflex is the simplest and fastest of the three reflex types. The electrical reflex latency varies from ~10 ms in spinal muscles to ~50 ms in distal lower limb muscles depending on the distance of respective muscle from the spinal cord or cranial nerve nuclei.

The latency consists of the sensory impulse conduction in sensory neurons, synaptic transmission and motor impulse conduction in the motor neurons. In addition, there is a notable time lag from the electrical activation of the muscle cells to the mechanical force produced by the muscle. In complex responses, the relative time for information processing is longer.

In the simple monosynaptic stretch reflex, muscle spindles sense the stretching of the muscle fibers. The information is mediated by the Ia sensory afferent nerves into the dorsal horn at the respective level of the spinal cord. These sensory nerve cells synapse with the motor neurons activating the corresponding muscle.

In more complex reflexes, an increasing number of inter-neurons are involved in mediating the reflex. The muscle activation is modulated also by the gamma motor neuron system. Reflexes are involved in voluntary and subsidiary movements, e.g. permitting the fluency of movements by controlling the agonist-antagonist muscle activation.

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Biographical Sketch

Dr Ville Leinonen, DMS was born in 1977, in Liperi, Finland. He is currently resident and post doc researcher in the Department of Neurosurgery, Kuopio University Hospital, Kuopio, Finland. He studied at the University of Kuopio, where he received his Licentiate of Medicine (MD) in 2002 and Doctor of Medical Sciences (DMS) in 2003.

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