J Rehabil Med 2009; 41: 986–987

MINI REVIEW

KINEMATIC AND NEUROPHYSIOLOGICAL MODELS: FUTURE APPLICATIONS IN NEUROREHABILITATION

Michelangelo Bartolo, MD[1,3], Romildo Don[4], Alberto Ranavolo, Eng[1,4], Mariano Serrao, MD, PhD[3,5] and Giorgio Sandrini, MD[1,2]

From the [1]Neurorehabilitation Unit, IRCCS Casimiro Mondino Institute of Neurology Foundation, [2]Department of Neurological Sciences, University of Pavia, Pavia, [3]Department of Neurorehabilitation 2, NEUROMED Institute IRCCS, Pozzilli (Isernia), [4]Laboratory of Physiology, Ergonomics, Posture and Movement, National Institute of Occupational Safety and Prevention, Monte Porzio Catone, Rome and [5]University of Rome "La Sapienza", Polo Pontino, Latina, Italy

This paper emphasizes the importance of developing kinematic and neurophysiological methods for evaluating motor and functional recovery in the field of neurorehabilitation. From a review of the literature, it is concluded that optoelectronic motion analysis and neurophysiological techniques, such as the study of nociceptive withdrawal reflex, might constitute useful applications for future research.

Key words: kinematic, neurorehabilitation, movement analysis.

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Correspondence address: Michelangelo Bartolo, Department of Neurorehabilitation 2, NEUROMED Institute IRCCS, via Atinense, 18, IT-86007 Pozzilli (Isernia), Italy. E-mail: michelangelo.bartolo@mondino.it

Submitted March 16, 2009; accepted June 15, 2009

INTRODUCTION

A systematic review of 123 randomized clinical trials (1) demonstrated that there is strong evidence that treatment intensity and task specificity are the main drivers of an effective treatment programme after stroke. In addition, training should be repetitive, functional, meaningful, and challenging for the patient (1, 2). In the past, several studies have been unable to prove the superiority of one type of conventional rehabilitation treatment over another (3, 4), but there is strong evidence that highly repetitive movement training can improve recovery (2, 4).

The use, in clinical practice, of robotic-aided rehabilitation (5, 6) is a promising new development. Robots allow patients to train independently, without the need for direct assistance from the therapist, and to improve their own functional performance. In particular, there is strong evidence that robot-assisted therapy improves treatment compliance and increases exercise intensity (7).

LITERATURE REVIEW

A search of the scientific literature showed that, while many rehabilitation treatments, including robotic therapy, have been used (1, 4, 7), there is great difficulty in measuring motor recovery, functional recovery, and social participation, also because they concern different levels of complexity for the analysis (form neurophysiological basis to environmental interactions). Hence, research into the effects of robot-assisted therapy should focus on methods (e.g. kinematic analysis, neurophysiological techniques) for differentiating between recovery due to neural reorganization and recovery attributable to adaptive strategies.

In the evolution of neurorehabilitation techniques, trunk stability was considered an essential component of balance and coordinated use of the extremities in daily functional activities. Trunk muscles work together, and modulation of their strength, by means of appropriate neural control is important in trunk stability and limb movements (8–10). There is ample evidence that the trunk is part of the prehension system, regardless of whether upper arm and trunk motor programmes are dependent or independent of each other (11). Recent studies of dynamic reaching showed that trunk bending and shoulder flexion-extension are involved in motor action earlier than previously believed. The importance of trunk control in functional rehabilitation has long been emphasized by many authors (12), and trunk control also emerges as an important factor in evaluation scales, such as the activities of daily living (ADL) or the Sitting Balance Test, where it has repeatedly been identified as a major predictor of motor and functional recovery after stroke (13–15).

MOVEMENT ANALYSIS

Motion analysis has become a tool commonly used to assess the neurophysiological and biomechanical features of human posture and movement, as technical advances and procedural improvements have made it possible to reduce errors due to the recording system and to soft tissue artefacts (16–19). It is important to consider that even though the spine has a multi-segmental structure, its function in whole-body motor and postural tasks is a global one. Moreover, structurally, the trunk musculature is characterized mainly by its linking of non-adjacent vertebrae, a feature that explains its diffuse rather than local control of posture and motion. Movement analysis may be particularly useful for assessing postural and motor abnormalities involving the whole spine, because it provides quantitative data relating to features such as trunk curvatures and flexibility, instead of only angles and ranges of motion (ROM).

 doi: 10.2340/16501977-0413
 ISSN 1650-1977

For this reason, the development of global models for assessing the whole spine regarded as a deformable body should be integrated with ones used for the lower (20) and upper (21) limbs.

NOCICEPTIVE WITHDRAWAL REFLEX

Kinematic methods and neurophysiological techniques, such as the nociceptive withdrawal reflex (NWR) could be employed to evaluate aspects of motor and functional recovery after rehabilitative intervention.

The NWR is a defensive response by which a limb is withdrawn from a painful stimulus by activating a complex neural network located in the spinal cord, which involves different muscles (22). The study of NWR has been used for examining changes in spinal cord function during rhythmic lower limb movements in humans (22). The NWR is easily recorded in several limb muscles as a clear and stable electromyography (EMG) response after painful electrical stimulation of several nerves. Although the flexion synergy evoked by painful stimuli serves a primarily protective function, various studies have shown that the NWR also fulfils a more complex motor function. Hand motor function is particularly important in humans for reaching and grasping, as well as for exploring and manipulating objects, and arm and hand movements are under more complex neural control than leg and foot movements.

Because the inter-neural network mediating NWR responses is included in the descending motor pathways, it could be hypothesized that studying the NWR during movement in hemiparetic patients might furnish pathophysiological information possibly useful for the planning of rehabilitation treatment. Although the flexion synergy evoked by painful stimuli serves a primarily protective function, various studies have shown that the NWR also fulfils a more complex motor function. The few studies that have investigated spinal reflexes during rhythmic upper limb movements have shown, in some muscles, a phase-dependent modulation of the kind observed in the lower limbs during walking. However, these studies considered cutaneous-muscular reflexes evoked by moderate, non-painful stimulation and evaluated during active or passive rhythmic cyclical movements constrained by a hydraulic ergometer (22). Therefore, data on the modulation of spinal reflexes after painful stimulation during arm movements are currently lacking. Study of the modulation of the NWR during voluntary movements of the upper limb (e.g. reaching and grasping, exploring and manipulating objects) may broaden understanding of the spinal mechanism involved in this complex motor function.

CONCLUSION

Kinematic and neurophysiological techniques, such as the study of NWR for the upper limb, represent methods to produce repeatable measurements. As already reported by a number of scientific papers (7, 23), these methods could be useful for evaluating the effects and efficacy of rehabilitation treatments, particularly robotic rehabilitation programmes, and should constitute useful applications for future research.

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