Neurophysiologie Clinique/Clinical Neurophysiology (2015) 45, 335—355

ELSEVIER MASSON

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Neurophysiologie Clinique Clinical Neurophysiology

REVIEW/MISE AU POINT

Gait post-stroke: Pathophysiology and rehabilitation strategies

La marche après accident vasculaire cérébral : physiopathologie et stratégies de rééducation

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Received 10 July 2015; accepted 22 September 2015
Available online 4 November 2015

KEYWORDS
Stroke;
Gait;
Posture;
Balance;
Pathophysiology;
Rehabilitation

Summary We reviewed neural control and biomechanical description of gait in both non-disabled and post-stroke subjects. In addition, we reviewed most of the gait rehabilitation strategies currently in use or in development and observed their principles in relation to recent pathophysiology of post-stroke gait. In both non-disabled and post-stroke subjects, motor control is organized on a task-oriented basis using a common set of a few muscle modules to simultaneously achieve body support, balance control, and forward progression during gait. Hemiparesis following stroke is due to disruption of descending neural pathways, usually with no direct lesion of the brainstem and cerebellar structures involved in motor automatic processes. Post-stroke, improvements of motor activities including standing and locomotion are variable but are typically characterized by a common postural behaviour which involves the unaffected side more for body support and balance control, likely in response to initial muscle weakness of the affected side. Various rehabilitation strategies are regularly used or in development, targeting muscle activity, postural and gait tasks, using more or less high-technology equipment. Reduced walking speed often improves with time and with various rehabilitation strategies, but asymmetric postural behaviour during standing and walking is often reinforced, maintained, or only transitorily decreased. This asymmetric compensatory postural behaviour appears to be robust, driven by support and balance tasks maintaining the predominant use of the unaffected side over the initially impaired affected side. Based on these elements, stroke

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http://dx.doi.org/10.1016/j.neucli.2015.09.005
0987-7053/

rehabilitation including affected muscle strengthening and often stretching would first need to correct the postural asymmetric pattern by exploiting postural automatic processes in various particular motor tasks secondarily beneficial to gait.

MOTS CLÉS
Accident vasculaire cérébral ;
Marche ;
Posture ;
Équilibre ;
Pathophysiologie ;
Rééducation

Résumé Le contrôle nerveux et la biomécanique de la marche chez le sujet sain et le sujet hémiplégique ainsi que les stratégies de rééducation au regard de la physiopathologie de la marche après accident vasculaire cérébral (AVC) ont été passés en revue. Chez le sujet sain ou hémiplégique, un contrôle moteur de type modulaire tâche-dépendant assure simultanément le support antigravitaire, le contrôle de l'équilibre et la déambulation au cours de la marche. L'hémiparésie après AVC est due à une interruption de voies nerveuses descendantes habituellement sans lésion directe des structures du tronc cérébral et du cervelet impliqués dans le contrôle moteur automatique. Après AVC, la récupération d'une station debout et de la marche se fait habituellement avec un comportement postural impliquant davantage le côté non atteint dans le contrôle du support et de l'équilibre, probablement suite à la faiblesse musculaire initiale du côté atteint. Divers types de rééducation sont pratiqués, visant directement le comportement musculaire ou des tâches posturales ou de locomotion en utilisant un équipement plus ou moins sophistiqué. Bien que la faible vitesse de marche s'améliore souvent avec le temps ou après diverses rééducations, le comportement postural asymétrique est souvent renforcé, maintenu ou seulement réduit transitoirement. Ce comportement postural asymétrique apparaît robuste, avec utilisation prédominante du côté non atteint pour assurer les tâches posturales antigravitaires. Ainsi chez les patients post-AVC, il est suggéré que la rééducation, incluant des renforcements et étirements des muscles parétiques, associe aussi divers exercices impliquant une utilisation posturale automatique des muscles parétiques pour corriger le comportement postural asymétrique et en tirer un bénéfice secondaire sur la marche.

Introduction

Walking dysfunction is a major problem for many subjects afflicted by stroke [2,109] and it causes difficulties in performing daily activities. Furthermore, there is a high risk for falls at all stages after stroke [6,59,254] and walking has been reported to be the event when falling most often occurs in community-dwelling stroke survivors [100]. Additionally, improving walking, with respect to safety and speed, is a major goal for stroke subjects in rehabilitation [59,193]. Discrimination between true recovered and compensatory movement patterns is increasingly emphasized in stroke rehabilitation nowadays (e.g. [20,140]), and for discriminative purposes, the quality of movement patterns needs to be observed, registered and analysed [146]. Moreover, our understanding of underlying mechanisms behind the emergence of both true recovery and compensation is still poor [20,140,248]. From the research perspective, the number of published neurophysiological studies regarding walking is rapidly expanding and is providing new knowledge about neural and biomechanical control including kinetic, muscle activation and kinematic data from typical and from post-stroke gait. These results might contribute to a deeper understanding of implicit factors influencing the mechanisms for true recovery post-stroke. From the clinical research side, the number of systematic reviews scrutinizing gait rehabilitation strategies post-stroke is also increasing, and there is an on-going discussion regarding what the optimal gait training models might be. The aims of the current review article are:

- to provide an update of the comprehensive new neurophysiological knowledge about typical and post-stroke gait reported in recent years;
- to give an overview of most of the gait rehabilitation strategies currently in use or in development;
- to supply a synthesis of research results and effects of current gait training models after stroke and to determine whether these models have implemented the new knowledge in practice.

Physiology of typical gait

Neural control of gait

In humans, bipedal locomotion is a motor task where the control system, in each step, needs to support body weight, provide forward and lateral stability and maintain forward progression. Thus, the postural antigravity control which provides body support and balance control to prevent falling is continuously associated with progression [165,177,260]. In addition, adaptation allows the adjustment of gait patterns to the environment [195]. The articulated body segments with quite different mass and inertia are linked by muscles with their own idiosyncratic viscoelastic characteristics, and their totality is responsible for the production of force and kinematics. The consequence is that each single joint movement involves dynamic interactions with the other segments of the kinematic chain inducing postural disturbance