New insights into the use of robotic gait training

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Exoskeletons: Revolutionizing Neurorehabilitation and Enhancing Patient Outcomes

Exoskeletons represent a paradigm shift in neurorehabilitation, providing a novel avenue for restoring mobility and enhancing independence among individuals with neurological or musculoskeletal impairments. The versatility of exoskeleton devices (including the *Lokomat*, *ReWalk*, *Ekso Bionics*, *Wandercraft*, etc.) allows for customized interventions tailored to the needs and capabilities of each patient. Furthermore, the varied applications of exoskeletons, ranging from treadmill-based systems to free space movement, underscore the adaptability of this technology in addressing a wide spectrum of patient conditions and rehabilitation goals. It is noteworthy that the vestibular and oculomotor control differs between treadmill-based systems like the *Lokomat* and free space movement, highlighting the distinct stimulation experienced by patients. Thus, exoskeletons offer a different stimulation and learning compared to traditional treadmill-based rehabilitation and allow better rehabilitation outcomes. Furthermore, by changing the patient-system interaction it changes the way patients learn (implicit, explicit, or perceptual). In the case of over-ground training (exoskeleton training), patients perceive more perceptual learning depending on the movement.

Electromyography for fine-tuning in Robotic Gait Training

The integration of EMG data into exoskeleton training protocols offers valuable insights into muscle activation patterns and motor control strategies employed by patients. By analyzing EMG signals, clinicians can tailor exoskeleton assistance to target specific muscle groups and movement patterns, facilitating more efficient gait rehabilitation. Moreover, advancements in EMG technology hold promise for real-time feedback systems that dynamically adjust exoskeleton parameters based on the patient's neuromuscular response, enhancing the effectiveness and personalization of robotic gait training by adjusting the lateral displacement, step length, and swing time (see **Figure 1**).

Studies such as Gandolla et al. (2018) have explored automatic fine-tuning settings to address challenges encountered during forward gait training. This research highlights the intricate interplay between neuromuscular activity and exoskeleton assistance, emphasizing

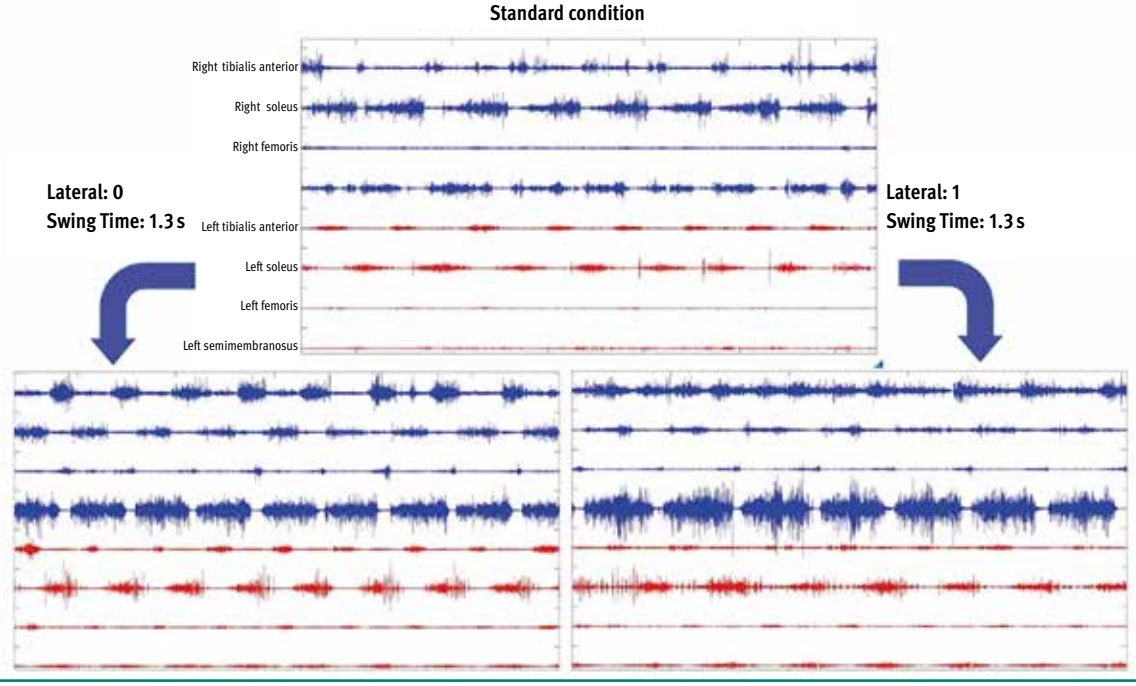

Figure 1. A) Myosuit: Patient with incomplete tetraplegia (25+ years since injury) walks without assistance wearing the Myosuit. **B)** Stability-Mobility Concept Myoshirt: Arm elevation assistance in patients with shoulder instability and muscular weakness. Source: SMS Lab. ETH Zurich

the importance of optimizing stimulation parameters to maximize rehabilitation outcomes.

Lateral and Backward Movements in Robotic Gait Training

Meta-analyses have highlighted the efficacy of backward training in improving gait patterns, velocity, and balance control, particularly in stroke patients. Integrating different movement patterns (forward, backward, and lateral movements) within sessions enhances compensation of the non-affected side and trunk control. Training sessions encompassing all gait movements, as observed in the Hospital Valduce, result in reduced trunk displacements, indicating a holistic approach that impacts lower limb control, trunk stability, visuomotor integration, and vestibular control. The impact of these multi-movement sessions can be observed immediately following the intervention, thereby illustrating a rapid acute relearning.

Future Horizons

In conclusion, using the flexibility of exoskeletons like Wandercraft, including forward, lateral, and backward training, alongside fine-tuning strategies, holds significant potential for enhancing motor control and rehabilitation outcomes. Incorporating such advancements promises a more tailored and effective approach to exoskeleton rehabilitation. The dynamic nature of exoskeleton training, combined with insights from EMG studies and the integration of different movements, opens new avenues for optimizing patient rehabilitation and improving overall quality of life. As research in this field continues to evolve, it is essential to embrace innovative technologies and multidisciplinary approaches to maximize the benefits of exoskeleton-assisted gait training and promote long-term recovery for individuals with mobility impairments.

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