TREATING GAIT ASYMMETRY AFTER STROKE: BASIC AND CLINICAL RESEARCH INSIGHTS

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DESCRIPTION:

Asymmetry is a hallmark of poststroke hemiparesis. We will review the biomechanical and neuromotor factors that contribute to asymmetric walking, including an overview of the cortical and neuromuscular changes observed after stroke. Following these foundational talks, we will discuss the influence of asymmetry on actual and perceived walking function and review novel therapies and technologies that have been introduced to restore more symmetrical walking after stroke. Finally, we will discuss why the results of our interventions have been mixed and how a more individualized approach that accounts for poststroke heterogeneity can improve outcomes.

LEARNING OBJECTIVES AND COURSE CONTENT:

Objective 1: Understand the clinical relevance of identifying and treating asymmetrical walking.

Why do we care about poststroke gait asymmetry?

- Gait asymmetries are interlimb deviations in kinematic, kinetic, or spatiotemporal parameters that are beyond what is observed in healthy, age-matched controls.
- Gait asymmetries arise from asymmetrical neuromotor abilities and are associated with low endurance, high metabolic cost, impaired balance, and reduced physical activity.
- There is also a subjective cost or perceived stigma of walking with an abnormal gait.

Treating poststroke gait asymmetry is complicated

- Gait asymmetry is multi-dimensional. For example, although step length asymmetry is often viewed as a spatial asymmetry, it results from asymmetries in both foot placement and step timing, thus requiring different interventions for different individuals.
- A common misconception is that reducing gait asymmetry will result in improvements in speed, endurance, metabolic cost, and balance; unfortunately, training related improvements in asymmetry are not always associated with improvements in these factors. In fact, for some individuals, reductions in asymmetry lead to an increase in metabolic cost and reduced balance.
- Despite having the capacity to produce more symmetric walking patterns, gait asymmetries persist into the chronic phase of stroke recovery.
- These findings suggest that reducing gait asymmetries may not be the best target for intervention. Or, more controversially, perhaps altering a patient’s gait asymmetry may not be in the patient’s best interest. That is, what appears to be abnormal may, in fact, be optimal for some individuals.
- Ideally, it would be possible to identify, on a case-by-case basis, who would benefit from treatments that target reduced asymmetry. Or, more challenging, to identify which fundamental abilities are lacking in patients who do not benefit from symmetry-inducing interventions, and how to best provide those abilities so that all patients with gait asymmetries are able to benefit from symmetry-reducing treatments.
Objective 2: Describe cortical and neuromuscular changes underlying asymmetrical walking.

Insights from preclinical models of stroke recovery

- The complexity and heterogeneity of neuromotor impairment in people poststroke, combined with the inherent limitations of clinical research, make it difficult to investigate the underlying causes of gait disorders, muscle dysfunction, and frailty.
- The development and use of preclinical models are extremely important steps in rehabilitation sciences research. Clinically-relevant animal models have the potential to inform rehabilitation research and accelerate its translation into the clinic.
- The ankle plantarflexor and dorsiflexor muscles play key roles during walking, contributing heavily to the forward propulsion of the body’s center of mass and the limb’s ground clearance during walking. These muscles are typically highly impaired after stroke.
- Animal models of stroke recovery have shown muscle adaptations as early as 2 weeks following induction of hemorrhagic stroke, with muscle fiber types shifting from faster to slower—a change associated with weaker and slower muscle contraction.
- Importantly, these neuromuscular changes appear to be influenced by factors other than physical activity, suggesting a need for treatments that specifically target involved muscles and fiber types.

The relationship between muscle function changes after stroke and locomotor asymmetry

- Recent human trials extend this work and elucidate the relationship between poststroke gait asymmetry and muscle-level impairments.
- Although the majority of patients present with muscle weakness, appropriate treatment selection requires understanding the nature of that weakness. Indeed, weakness may be the result of a reduction in force generating ability (owing to atrophy or changes in muscle composition), or to reduced voluntary activation of the residual force generating ability of the muscle (i.e., an activation deficit).
- In recent work examining the relationship between ankle plantarflexor muscle function and poststroke gait asymmetry, reduced voluntary activation of the plantarflexor muscles, not a reduced force generating ability, was observed to contribute to propulsion asymmetry.
- Importantly, by leveraging a compensatory reliance on the nonparetic limb for propulsion, patients with large voluntary activation deficits were able to achieve similarly fast walking speeds as those with near normal muscle activation, highlighting the fact that gross clinical measures often fail to detect gait asymmetries.

The relationship between cortical adaptations after stroke and locomotor asymmetry

- These preclinical and clinical studies both demonstrate the value of probing for the underlying source of poststroke neuromuscular impairments to personalize gait therapy, and indicate that poststroke locomotor asymmetry has its basis in the cortical and subcortical adaptations that occur after stroke.
- Indeed, patients with more symmetric corticomotor excitability of the paretic and nonparetic ankle plantarflexor muscles are more likely to use an ankle plantarflexion propulsion strategy to modulate walking speed.
- Moreover, atypical interhemispheric interactions between the lesioned and nonlesioned motor cortical regions of the lower limbs appears to influence the locomotor strategy of people poststroke. Specifically, reduced interhemispheric inhibition during muscle contraction (compared to healthy controls) is positively correlated to gait symmetry.
- These studies suggest that both cortical excitability of the paretic limb muscles and interhemispheric inhibition may need to be balanced to maximize poststroke gait recovery.
Objective 3: Identify targeted treatments that address heterogeneous impairments poststroke

Neuromuscular interventions
- Emerging neuromodulatory interventions such as brain and spinal cord stimulation, as well as pharmacological interventions, hold substantial promise to target impaired activation of the lower limb muscles and asymmetric corticomotor input.
- One clinically accessible neuromodulatory intervention is functional electrical stimulation (FES). Recent work has shown that a single session of walking with plantarflexor muscle FES can increase corticomotor symmetry and increase ankle plantarflexor torque symmetry.
- Longer-term training with FES has similarly resulted in long-lasting changes in plantarflexor torque symmetry and substantial reductions in the metabolic cost of walking, alongside clinical improvements in speed and distance; however, not all patients respond similarly. Those with a propulsion-based walking strategy at baseline benefit the most.

Biomechanical interventions
- When designing treatments, it is important to consider that muscle forces interact with and influence limb kinematics to produce movement. That is, unaddressed kinematic deviations may reduce the impact that neuromuscular interventions have on gait function.
- For example, one key kinematic variable to consider is the trailing limb angle, defined as the positioning of the trailing limb behind the body during the terminal stance phase of gait. Increased ankle plantarflexion results in improved propulsion only when the limb is sufficiently behind the body; however, a number of factors reduce the trailing limb angle.
- The complexity of poststroke gait asymmetries arising from primary and secondary sources is evidenced in recent robotic-based intervention studies evaluating the effects of targeting only the ankle joint during hemiparetic walking. For some individuals, targeted robotic assistance of ankle dorsiflexion and plantarflexion leads to reductions in hip compensations and increased trailing limb angle, whereas in others it does not.
- Individuals who continue to present with proximal compensations when provided with distal joint assistance likely require staged, multimodal treatments. For example, deficits in joint passive range of motion or the ability to dissociate trunk and limb motion during walking could each prevent an adequate trailing limb angle, and thus hinder gait restoration.

Perceptual interventions
- Gait asymmetry may also be due to decreased awareness of gait asymmetry. Interventions that increase a patient’s perception of asymmetry may be warranted for some.
- For example, a person’s asymmetry can be augmented to levels beyond their usual asymmetry using a split-belt treadmill.
- Biofeedback interventions that provide patients with information about their walking patterns during gait training, and ask them to make changes based on this information, also hold substantial potential to modify gait asymmetry.

Toward treatment personalization: prediction and intervention
- One of the primary challenges in addressing asymmetry after stroke is that individuals with similar levels of asymmetry may have entirely different underlying impairments. As a result, interventions for reducing asymmetry need to be personalized.
- Given the heterogeneity of neuromotor impairment after stroke and the variety of interventions available across different domains of impairment, an evidence-based mapping of clinical presentation onto treatments is needed.
- A holistic understanding of individual patient’s deficits is particularly crucial as it is likely that certain intervention approaches may reduce asymmetry while penalizing other locomotor objectives, such as speed, stability, and efficiency.
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