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Short Communication

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# EMG-Based Biofeedback to Improve Motor Control in Children with Dystonia

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## Abstract

The scarcity of effective treatment options for children with dystonia represents an important clinical challenge. In this framework, biofeedback training is a promising non-invasive treatment candidate. Indeed, rehabilitation tools able to provide augmented sensory information may be used by children to better calibrate and modulate muscle activations to attain improved motor control. Recently, biofeedback paradigms based on surface electromyographic activity of task-related muscles have been developed and tested. These studies, by leveraging different sensory channels, such as visual and haptic modalities, showed that children with dystonia have the ability to gain partial control over muscle activations, resulting in clinical improvements. Future studies should adopt more sensitive and accurate outcome measures with the ability of capturing small motor changes, in order to quantitatively and reliably assess the benefits of biofeedback training in children with dystonia.

### Keywords

Biofeedback; Rehabilitation; Childhood dystonia; Electromyographic activity

## Discussion

Biofeedback provides the subject with instant, reliable feedback of performance, making covert physiological processes more manifest. The aim of biofeedback is to improve the efficacy of the rehabilitation treatment by allowing patients to adjust their movements according to the feedback of performance. Additionally, biofeedback training is able to capture and maintain the subject's attention and to allow the participant to exercise in immersive settings.

The neurological mechanisms underlying biofeedback training in children with dystonia are not well understood yet. It is known that patients with dystonic symptoms may also be characterized by inefficient sensory information. One hypothesis is that the use of biofeedback may enhance neural plasticity by involving auxiliary sensory inputs, thus augmenting the reliable feedback signal available to the sensorimotor circuits. It is likely that this additional piece of information may be used to reinforce correct and natural feedback loops according to an Hebbian-like approach. In this framework, rehabilitation tools able to provide augmented sensory information may be used by children to better calibrate and modulate muscle activations to attain improved motor control. Since current interventions for children with dystonia, which include physical and occupational therapies, pharmacological approaches, and deep brain stimulation, are often only partially successful in controlling the child's symptoms, there is a strong need to investigate new treatment options. Biofeedback training is one of the promising non-invasive candidate [1].

It has been shown that voluntary movement in children with dystonia is characterized by inappropriate muscle patterns, likely due to an altered ability to remove noisy and unwanted components of movement [2]. It is still unclear whether such dysfunction arises from unreliable sensory feedback, incorrect motor commands, or both. In case the presence of unreliable sensory feedback contributes to movement dysfunction in dystonia, providing brain circuitry with reliable additional information of performance may result in an improved control over voluntary movement. Indeed, while the short-term effect of biofeedback may consist of improved awareness of the ongoing movement, on the long-term such technique has the potential to facilitate plasticity of the neural pathways that encode motor commands. To this end, muscle activity seems to be the most relevant information to be fed back to patients and biofeedback paradigms based on surface electromyographic activity (EMG) of task-related muscles have been recently developed and tested. The potential of this kind of treatment in children with dystonia may be related to increased attention and enhanced sensation of muscle contraction reinforcing proprioception [1].

Young et al. [3] studied a tracking task with visual feedback of muscle co-contraction levels in children with dystonia and they showed that patients were able to control co-contraction by directing specific attention to the aberrant muscle activations.

In a recent study, our group leveraged the haptic modality to enhance motor control in dystonia [4]. During a spiral tracking task, tested on children with and without dystonia, virtual table friction and background color changed according to the brachioradialis EMG activity. Results showed that biofeedback training had a significant positive impact on the control of movement in children with dystonia. Such an improvement was shown to significantly correlate with the clinical scale score.

Notwithstanding the promising results, the above mentioned studies suffered from some limitations that prevented children from using surface EMG biofeedback in daily practice. Indeed, these early paradigms required conscious attention or effort and devices were cumbersome and not battery-operated, thus difficult to be adopted in domestic settings. To this end, Bloom et al. [5] developed a wearable device that provides the subject with a mechanical tactile stimulation. The head of the device, which contains a silent vibrating motor mounted on a surface EMG electrode, is intended to be placed and provide feedback at the site of the most impaired muscle. The fast processor and the use of a nonlinear filter to estimate the force underlying the EMG signal [6] allow the device to implement online biofeedback and provide the subject with a vibration, whose speed is proportional to the activation level of the target muscle. The peculiar features of this device, which include small dimensions, silent mode,

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and battery-operated power supply, allow the child to wear it multiple hours a day during daily activities. Early tests of the biofeedback device on children with cerebral palsy revealed improvement in motor performance. However, changes in motor skill were assessed through clinical scales and questionnaires, which are known to be characterized by limitations, such as reduced granularity and inter-/intra-examiner reliability.

To overcome the current limits of the literature investigating the efficacy of biofeedback training in children with primary and secondary dystonia and to quantitatively assess the benefits of the wearable EMG biofeedback device, NIH has funded a multi-center clinical study coordinated by Professor Terence Sanger from the University of Southern California. The study presents a long-term protocol which encompasses at-home daily activities and laboratory-based experiments that propose experimentally controlled versions of tasks relevant to the child's daily life, such as writing and self-feeding. Importantly, changes in motor performance are assessed using quantitative and accurate outcome measures, particularly suitable for children with dystonia, such as changes in the speed-accuracy trade-off [7] and quantitative indices to evaluate the proper recruitment of the correct muscle patterns [2]. Finally, the collaboration of multiple clinical partners allows the inclusion of children with multiple etiologies, with the aim of gaining insights into the different underlying mechanisms of primary and secondary dystonia.

Overall, these works shed light on the potential effectiveness of biofeedback training in helping children with dystonia to gain improved control over specific muscles during voluntary motion. Since symptoms of dystonia are highly-disabling and strongly influence the child's everyday life, from school activities to social interaction, the investigation of novel potential effective treatments suitable for these children is a crucial point that requires the attention of future research work.

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