Toe walking

Voluntary toe walking in adults is characterized by feedforward control of ankle muscles in order to ensure optimal stability of the ankle joint at ground impact. Toe walking is frequently observed in children with cerebral palsy, but the mechanisms involved have not been clarified. Here, we investigated maturation of voluntary toe walking in typically-developing children and typically-developed adults and compared it to involuntary toe walking in children with cerebral palsy. Twenty-eight children with cerebral palsy (age 3-14 years), 24 typically-developing children (age 2-14 years) and 15 adults (mean age 30.7 years) participated in the study. EMG activity was measured from the tibialis anterior and soleus muscles together with knee and ankle joint position during treadmill walking. In typically-developed adults, low step-to-step variability of the drop of the heel after ground impact was correlated with low tibialis anterior and high soleus EMG with no significant coupling between the antagonist muscle EMGs. Typically-developing children showed a significant age-related decline in EMG amplitude reaching an adult level at 10-12 years of age. The youngest typically-developing children showed a broad peak EMG-EMG synchronization (>100 ms) associated with large 5-15 Hz coherence between antagonist muscle activities. EMG coherence declined with age and at the age of 10-12 years no correlation was observed similar to adults. This reduction in coherence was closely related to improved step-to-step stability of the ankle joint position. Children with cerebral palsy generally showed lower EMG levels than typically-developing children and larger step-to-step variability in ankle joint position. In contrast to typically-developing children, children with cerebral palsy showed no age-related decline in tibialis anterior EMG amplitude. Motor unit synchronization and 5-15 Hz coherence between antagonist EMGs was observed more frequently in children with cerebral palsy when compared to typically-developing children and in contrast to typically-developing participants there was no age-related decline. We conclude that typically-developing children develop mature feedforward control of ankle muscle activity as they age, such that at age 10-12 years there is little agonist-antagonist muscle co-contraction around the time of foot-ground contact during toe walking. Children with cerebral palsy, in contrast, continue to co-contract agonist and antagonist ankle muscles when toe walking. We speculate that children with cerebral palsy maintain a co-contraction activation pattern when toe walking due to weak muscles and insufficient motor and sensory signalling necessary for optimization of feedforward motor programs. These findings are important for understanding of the pathophysiology and treatment of toe walking [1)].

1)
Lorentzen J, Willerslev-Olsen M, Hüche Larsen H, Farmer SF, Nielsen JB. Maturation of feedforward toe walking motor program is impaired in children with cerebral palsy. Brain. 2019 Feb 4. doi: 10.1093/brain/awz002. [Epub ahead of print] PubMed PMID: 30726881.