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The effect of child-oriented balance training with a special focus on compensatory postural responses to anticipated and non-anticipated perturbations

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From a developmental perspective, postural control matures non-linearly during childhood and does not achieve an adult-like level before the age of around 13 years. The non-linear development is most probably caused by a transition phase between the ages of 4 to 8 years. Within this transition phase, children learn to integrate different sensory inputs and to coordinate feedback and feedforward postural control strategies. As the evidence that postural control can be trained effectively in childhood is currently weak, it could be hypothesized that the immature postural control system in children may prohibit training gains in response to balance training. Moreover, the behavior of children in feedback and feedforward controlled situations could provide further knowledge about the development and trainability of postural control in children. To test this, responses to anticipated and non-anticipated perturbations can be compared. Anticipated perturbations indicate feedforward control strategies whereas non-anticipated perturbations provide information about feedback control. Although behavioral postural responses to perturbations are widely studied in children, the impact of balance training on such responses is hardly explored. Thus, the aim of this thesis was to investigate whether balance training can improve postural control in children. In addition, the current thesis focused on feedback and feedforward controlled responses to externally induced perturbations. Additionally, the underlying mechanisms of responses to anticipated and non-anticipated perturbations were analyzed in adults with neurophysiological techniques to provide more detailed insights into the control of anticipated and non-anticipated perturbations.

Children of three different age groups (6–7, 11–12, and 14–15 years) were exposed to balance training, which was tailored to the needs of the children (i.e. child-oriented). Before and after the training, postural control was assessed in static and dynamic standing tasks as well as in situations with anticipated and non-anticipated perturbations. Moreover, the preparation and control of anticipated and non-anticipated perturbations was assessed in adults with transcranial magnetic stimulation (TMS) and peripheral nerve stimulation (PNS) to investigate the underlying neural mechanisms.

The child-oriented balance training resulted in improvements in dynamic standing tasks and in perturbed situations. Interestingly, the youngest group improved in the standing dynamic task to a larger extent than the two older groups. When considering the responses to perturbations, 11- to 12-year-old children profited more in anticipated than in non-anticipated perturbations from the balance training whereas 6- to 7-year-old children adapted similarly in both conditions. Neurophysiological measurements in adults indicated that mainly cortical centers are involved when generating appropriate responses to anticipated perturbations.

The results of the present thesis demonstrate that postural control can be successfully trained in children from the age of six years onwards. Thus, the immaturity of the postural control system did not prohibit improvements in response to balance training in children. However, as soon as the processing of the postural task becomes more complicated (i.e. feedforward control in anticipated perturbations), children older than 10 years benefit more from the balance training than younger children. It is therefore assumed that the central nervous system of young children is too immature to apply and integrate feedforward control strategies into the compensatory feedback control of postural perturbations. The last study applied neurophysiological measurements in adults and indicated that cortical regions are largely involved in the preparation of anticipated perturbations. Moreover, it might be speculated that the observed task-specific reflex adaptations at the spinal level during anticipated perturbations are also controlled from cortical regions. The large cortical involvement for the preparation of anticipated responses may also explain differences between age-groups as it is known that cortical capacities mature during childhood.

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