

The ipsilateral silent period in boys with attention-deficit/hyperactivity disorder

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Abstract

Objective: Characterize maturation of transcallosal inhibition (ipsilateral silent period [iSP]) in attention deficit/hyperactivity disorder (ADHD) using transcranial magnetic stimulation (TMS).

Background: Maturation of the iSP is related to acquisition of fine motor skills in typically developing children suggesting that dexterous fine motor skills depend upon mature interhemispheric interactions. Since neuromotor maturation is abnormal in boys with ADHD we hypothesized that iSP maturation in these children would be abnormal. We studied iSP maturation in 12 boys with ADHD and 12 age-matched, typically developing boys, 7–13 years of age.

Methods: Surface electromyographic activity was recorded from right first dorsal interosseus (FDI). During background activation, focal TMS was delivered at maximal stimulator output over the ipsilateral motor cortex.

Results: Maturation of finger speed in boys with ADHD was significantly slower than that in the control group. The iSP latency decreased with age in the control group but not in the ADHD group.

Conclusions: These findings suggest the presence of a complex relationship between abnormalities of certain interhemispheric interactions (as represented by iSP latency) and delayed maturation of neuromotor skills in boys with ADHD.

Significance: These data provide preliminary physiologic evidence supporting delayed or abnormal development of interhemispheric interactions in boys with ADHD.

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Keywords: Transcallosal inhibition; Interhemispheric interactions; Transcranial magnetic stimulation; Developmental disorders

1. Introduction

Shortened attention span and clumsy movements are typical of childhood and may result from immature interhemispheric interactions (Denckla, 1973; Rueckert et al., 1994). These juvenile neurobehavioral characteristics

gradually disappear so that by early adolescence children function at or near adult levels. Autopsy and imaging studies provide evidence that callosal myelination and cortical neuronal development mature over this same time period (Huttenlocher and Dabholkar, 1997; Yakovlev and Lecours, 1967).

Transcranial magnetic stimulation (TMS) may be a useful neurophysiologic tool to study maturation of interhemispheric interactions via the ipsilateral silent period (iSP) (Garvey and Gilbert, 2004). The iSP is a reduction of ongoing voluntary electromyographic (EMG) activity

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evoked by a stimulus applied to the motor cortex ipsilateral to the target muscle (Wassermann et al., 1991). There is convincing evidence that the iSP is mediated by the mid-body of the corpus callosum (Borojerdj et al., 1996; Meyer et al., 1998). We have previously reported age-related changes in both the latency and duration of the iSP in typically developing right-handed children. In addition, our prior work demonstrated an inverse relationship between iSP latency and finger tapping speed (Garvey et al., 2003). These data provide evidence of an association between maturation of fine motor skills and development of the functional capacities of underlying brain structures. More specifically, they suggest that latency of the iSP may reflect a class of interhemispheric interactions that contributes towards dexterous performance of fine motor control.

In addition to the general hyperactivity present in attention deficit/hyperactivity disorder (ADHD), boys with ADHD show abnormalities on fine motor examination. These manifest as slowed finger tapping and overflow movements that are qualitatively similar, but more prominent, than those seen in younger, typically developing children (Denckla and Rudel, 1978; Mostofsky et al., 2003). Unlike typically developing children, these neuromotor anomalies in boys with ADHD do not disappear until late adolescence suggesting a developmental lag (Cohen et al., 1967). Investigators speculate that these abnormalities may result from delayed or abnormal development of interhemispheric interactions. Functional neuroimaging studies in ADHD give further support to the hypothesis of a delay in development (Rubia et al., 2000).

A recent study using TMS concluded that ADHD was associated with abnormal transcallosal inhibition (Buchmann et al., 2003) based on differences in the iSP between a group of children with ADHD and a control group. One important finding in their study was that iSP latency tended to decrease with age in the ADHD group at a faster rate than in the control group. This finding is at variance with many prior studies, including those cited above, which demonstrate a developmental lag in neurobehavioral manifestations in children with ADHD when these are compared to typically developing children. The reason for this variance may lie in the fact that the control group in the study by Buchmann et al. (2003) comprised children with developmental disabilities (e.g. dyslexia) and neither this group nor the group with ADHD were compared with typically developing children.

The aim of this report was to compare iSP maturation in children with ADHD with iSP maturation in typically developing children with no psychiatric or developmental disorders. In this way, the non-ADHD results would more accurately represent normal development. Based on previous data which have shown a developmental lag in neuromotor function in boys with ADHD (Denckla and Rudel, 1978) and a relationship between maturation of iSP latency and development of finger tapping speed

(Garvey et al., 2003) we hypothesized that iSP maturation would be abnormal in boys with ADHD.

2. Subjects

Right-handed, 7–13 year old boys with ADHD and age-matched, typically developing right-handed boys (control group) were recruited for a study that was approved by the local Institutional Review Board. Children and their parents gave informed assent and consent, respectively, to take part in the study. Conners Parent and Teacher Rating Scale (Revised 1997) and Achenbach's Child Behavior Checklist (1991) were administered to all subjects in the study. Boys in the control group were free from neurological and psychiatric symptoms. These children had a Conners T score below 60. Boys with ADHD had their diagnosis confirmed by psychiatric interview (MLD or FXC). All met DSM-IV criteria for moderate to severe combined (inattentive and hyperactive) type ADHD, with a Conners T score above 65. Children with co-morbid neuropsychiatric conditions including tic disorders and learning disabilities were excluded from the study. All ADHD subjects were medication free for at least 7 days before the study.

3. Methods

3.1. Neuromotor assessment

Neuromotor function was assessed in each child with a modified version of the Physical and Neurological Examination of Subtle Signs (PANESS) (Denckla, 1985). Hand preference was assessed by asking each child to perform 14 common activities (e.g. brushing teeth, combing hair, throwing a ball). The time to complete 20 repetitive movements (finger taps) and sequential movements (successive finger taps) was then measured on the right hand. A finger speed score was calculated from the total time taken to perform repetitive and sequential finger tasks (lower scores = faster movements). Since mirror movements (as measured by the PANESS) did not appear to be related to the iSP in our previous study we did not include them in the present analysis (Garvey et al., 2003).

3.2. Electromyographic (EMG) recording

The surface EMG was recorded using 9 mm bipolar surface Ag/AgCl EMG electrodes (Electro-Cap International, Incorporated, Eaton, OH) placed over the right first dorsal interosseus (FDI) muscle in a belly tendon montage. EMG signals were amplified (Isolated Bioelectric Amplifier, SA Instrumentation Company, San Diego, CA) using band-pass filters of 100 Hz and 1 kHz. The level of muscle activation was monitored with real-time oscilloscope and auditory feedback. The signals were sampled

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