

## Reply to: The Geographic Variation in the Prevalence of Attention-Deficit/Hyperactivity Disorder the United States is Likely Due to Geographical Variations of Solar Ultraviolet B Doses and Race

To the Editor:

In his correspondence, Dr. Grant proposes an alternative explanation for our findings on the association between attention-deficit/hyperactivity disorder (ADHD) prevalence (PREV) and solar intensity (SI) (1). Whereas in our article we argue that the most likely mechanism is through effects on the circadian system, Dr. Grant proposes that the explanation of solar-related increases of vitamin D should be reconsidered. Indeed, the SI measure used in our analysis has both effects on the circadian system (via 464–484 nm blue light), as well as solar radiation changing 7-dehydroxycholesterol in the skin to vitamin D (via 290–315 nm ultraviolet B light). In our correlational analysis, these 2 effects could not be separated. We considered the vitamin D possibility before settling on circadian rhythm entrainment as the most likely hypothesis.

Dr. Grant states that the highest rates of ADHD are in states with high fractions of the population being African American, who have lower serum 25-hydroxyvitamin D [25(OH)D] levels than Caucasians. However, higher rates of ADHD, according to the original Centers for Disease Control and Prevention (CDC) report that we used in our analyses, were not found for African Americans but only in multiracial children (2), for which we controlled in our analysis. Rerunning our analysis with percentage African Americans per state (census data) added as a covariate also had no influence on the partial correlations between SI and ADHD PREV (2003:  $r = -.637 \rightarrow r = -.639$ ; 2007:  $r = -.580 \rightarrow r = -.597$  all  $ps < .000$ ). Finally, there are several states with a relatively low African American population (<2%) that have above average ADHD PREV rates (North Dakota, Iowa, Wisconsin, and Kansas), which further contradicts Dr. Grant's argument. Taken together, these results clearly suggest that skin color and consequent efficiency of vitamin D synthesis are not associated with ADHD prevalence in the data we analyzed.

In addition, there is no published literature suggesting a direct link between vitamin D and ADHD or ADHD complaints such as inattention, impulsivity, and hyperactivity in children. In a recent prospective longitudinal study in more than 2000 children (3), it was concluded that "vitamin D status during pregnancy or childhood does not seem to be related to behavioural problems in children." Furthermore, Humble *et al.* (4) reported decreased 25(OH)D in patients with autism and schizophrenia but not in the studied group of patients with ADHD. Also, no studies or case reports are found for ADHD and rickets (a childhood bone disorder caused by vitamin D deficiency).

When looking at CDC data on vitamin D deficiency and inadequacy [assessed with serum 25(OH)D], there was a slight increase from 1988 to 2002, but no change between 2001 and 2006 (5), whereas the same CDC reported a significant increase in self-reported ADHD PREV from 7.8% in 2003 to 9.5% in 2007 (2), suggesting these trends do not match. Finally, data from the U.S. Department of Agriculture based on a nationwide sampling of vitamin D contents of milk products (fortified vitamin D milk products) found an increase of 11% of vitamin D content in milk, between 2001 and 2007 (6), which also goes against the trend of increasing ADHD PREV between 2001 and 2007. Therefore, the scarcely available scientific data and U.S. trend data on vitamin D

deficiency and actual vitamin D content of fortified products are not supportive of an association between vitamin D and ADHD PREV, nor is there a theoretical explanation for this association.

In contrast, there are multiple studies suggesting an involvement of the circadian system in ADHD: 1) genetic and molecular alterations of the circadian clock (7,8); 2) circadian phase delay as measured with behavioural, endocrine, and molecular measures (8–10); 3) clinical effects of light therapy in ADHD using bright light where ultraviolet wavelengths were filtered out (11) and by chronobiological treatment with melatonin (12); and 4) a clear association of reduced sleep duration in children with attention problems and externalizing behavior [reviewed in Arns and Kenemans (13)]. Therefore, both from the theoretical perspective as well as based on supportive literature, the hypothesis involving circadian effects is the most plausible. Ultimately, the question will be resolved by further research testing the competing hypotheses.

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