Title
Cognition impact of sand and dust storms highlights future research needs?

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Zhihui Li and colleagues[1] have written a convincing paper establishing the association between prenatal timing and exposure to sand and dust storms and children's cognitive functioning in China. This research is undoubtedly important, given that an estimated 150 parties to the United Nations Convention to Combat Desertification are affected in some way by sand and dust storms.[2] Yet while a lot is known about the role of prenatal exposure to anthropogenic pollution and its effects on various health and cognitive outcomes, we know little about the role of prenatal exposure to sand and dust storms on these outcomes. In particular, Li and colleagues[1] are perhaps the first to link prenatal exposure to sand and dust storms with cognitive outcomes.

While the authors do a commendable job of connecting sand and dust storms exposure to cognitive function, future work in this area should focus on the mechanisms behind this association. Li and colleagues assume direct physical exposure linkages between sand and dust storms and damage to the fetal brain; however, at least from our perspective of having studied the effects of dust storms and pollution in west Africa,[3] there are lots of potential pathways through which dust and sand storms could affect long-term outcomes. Teasing apart Li and colleague's association to uncover the impact pathways involved will be crucial for informing any sort of policy response.

One of the most important and established effects of sand and dust storms is on economic outcomes, be they direct effects on economic activity (through flight disruptions, for example), or indirect effects on income through loss of agricultural output in rural areas, or labour productivity due to avoidance behaviour. Sand and dust storms can also spread disease (as in the case of meningitis in west Africa and avian influenza in Asia). Research has shown that income loss and disease in the in-utero environment can cause short-term and long-term effects on a range of outcomes.[4] A limitation of Li and colleagues' study is its inability to untangle the notion of direct exposure from a situation in which mothers are indeed completely able to prevent any direct dust exposure to the fetus, but where the child is affected by cognitive function declines in later life because of income loss or exposure to disease, not dust. If that were true, then the policy response should not be tailored to prevent mothers from being exposed to sand and dust storms, but rather, should focus on income generation or transfers or appropriate medical care for diseases that are likely to be transported by sand and dust storms.

A related concern is that sand and dust storms are strongly seasonal and typically take place in the winter and early spring, the same time of year in which coal-based central heating is provided in cities north of the Qinling-Huaihe line in China. The central heating policy contributes to ambient concentrations of fine and ultrafine black carbon and sulfate aerosol particulate matter; the effects of prenatal exposures to these pollutants are well-established.[5] The meteorological literature suggests that lower temperatures in early spring are associated with increased frequency of sand and dust storms,[6] but this would also lead to increased heating demand and thus increased prenatal exposure to damaging particulate matter. Simple next steps in this line of research would be to control for ambient $PM_{2.5}$ concentrations to isolate the effect of sand and dust storms effect and explore whether effects are heterogeneous for children exposed in utero to sand and dust storms but not central heating (ie, just south of the Qinling-Huaihe line or those exposed to the rarer off-season storms). The combination of different aerosol sources in northern China offers a unique and valuable opportunity to begin to untangle questions about the relative effects of different aerosol types.

Finally, Li and colleagues' work highlights the crucial need for research on the physical science side to enable exploration of potential mechanisms. The authors point to research on ultrafine particulate matter and its ability to cross the blood-brain barrier, but physical studies of sand and dust storms suggest a larger particle size distribution than ambient pollution.[7,8] More research is needed to understand the biological mechanisms underlying the effects of coarse-grain particulates on longer-term outcomes; alternatively, if it really is the very small particles doing the damage (even in largely coarse-grain events like sand and dust storms), then a

change is needed in the measurement paradigm, away from mass-based measurements (in which fluctuations in fine and ultrafine concentrations are noise, since mass scales with radius cubed) and towards particle size distribution measurements.

Li and colleagues' work provides an important step towards documenting the long-term effects of prenatal exposure to sand and dust storms. However, much remains to be done in terms of exploring pathways of effects, documenting behavioural responses to sand and dust storms, and better measuring particulate exposures.

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