AFCA are examined in a separate paper (unpublished data).

The effect sizes reported in this study are similar to those calculated in the meta-analysis by Schab and Trinh.[4] They estimated the effects of AFCA on hyperactivity to be 0·283 (95% CI 0·079–0·488), falling to 0·210 (0·007–0·414) when the smallest and lowest quality trials were excluded. It should be noted that this meta-analysis included studies of hyperactivity in clinical samples, whereas the present study was done on children in the general population with the full range of degrees of hyperactivity. These effect sizes recorded by Schab and Trinh are smaller than those reported for stimulant treatment for ADHD in children, for which one meta-analysis[20] reported a range of effect sizes from 0·78 (0·64–0·91) by teacher report to 0·54 (0·40–0·67) by parent report. We report effect sizes that average at about 0·18. Children with ADHD are generally about 2 SD higher on hyperactivity measures than those without the disorder,[21] thus an effect size of 0·2 is about 10% of the behavioural difference between them.

This study provides evidence of deleterious effects of AFCA on children's behaviour with data from a whole population sample, using a combination of robust objective measures with strong ecological validity, based partly on observations in the classroom and ratings of behaviour made independently by teachers and by parents in the different context of the home and applying double-blinded challenges with quantities of additives equal to typical dietary intakes. It also replicates the effects of mix A previously reported on a large sample (n=277) of 3-year-old children,[5] although significant effects were only seen with parental ratings in that study.

The specific deleterious compounds in the mix cannot be determined for the present study and need to be examined in subsequent studies. The effect of artificial colours needs to be differentiated from the effects of preservatives in a 2×2 design. Further investigation would also need to establish whether the age-related difference seen in the present study can be replicated—ie, the effects of mix A being greater for 3-year-old children than for 8/9-year-old children. We examined the effects of additives on changes in behaviour during an extended period in a community-based, double-blinded, placebo-controlled food challenge. A weakness in this approach is the lack of control over when the challenges are ingested in relation to the timing of measures of hyperactivity. This study design also needs extensive resources to obtain multisource and multicontext measures of hyperactivity. We have completed a pilot study showing that changes in hyperactivity in response to food additives can be produced within about 1 h. Therefore, future studies could use more feasible acute double-blinded challenges undertaken in more controlled settings.

The present findings, in combination with the replicated evidence for the AFCA effects on the behaviour of 3-year-old children, lend strong support for the case that food additives exacerbate hyperactive behaviours (inattention, impulsivity, and overactivity) in children at least up to middle childhood. Increased hyperactivity is associated with the development of educational difficulties, especially in relation to reading, and therefore these adverse effects could affect the child's ability to benefit from the experience of schooling.[22] These findings show that adverse effects are not just seen in children with extreme hyperactivity (ie, ADHD),[4] but can also be seen in the general population and across the range of severities of hyperactivity. Our results are consistent with those from previous studies and extend the findings to show significant effects in the general population. The effects are shown after a rigorous control of placebo effects and for children with the full range of levels of hyperactivity.

We have found an adverse effect of food additives on the hyperactive behaviour of 3-year-old and 8/9-year-old children. Although the use of artificial colouring in food manufacture might seem superfluous, the same cannot be said for sodium benzoate, which has an important preservative function. The implications of these results for the regulation of food additive use could be substantial.

Contributors

JS, JOW, and ES-B participated in the conception and design of the study. The Food Standards Agency assisted with the design of the study. DMC directed the execution of the study. AB, AC, DC, LD, EK, LP, and EP undertook assessments of the children and helped to develop the observational methods employed in the study. KG supervised and KL executed the nutritional aspects of the study in relation to the preparation of suitable challenge drinks and advice on diet for parents. DMC and JS analysed the data and wrote the manuscript with input from all the authors.

Conflict of interest statement

We declare that we have no conflict of interest.

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