

## 1. Introduction

Children's performance in school has long term effects on health determinants and educational attainment, which is required for the growth of nations in a competitive, knowledge-based, globalized world (1,2). Good nutrition has an important role in child development and learning. Malnutrition is associated with less energy and interest for learning, increased risk of multiple micronutrient deficiencies, alterations in brain growth and structure and impaired cognitive development (3,4). Empirical evidence shows that good health and nutrition are prerequisites for effective learning. Dietary aspects such as breastfeeding appear to be beneficial for cognition in children (5). Most studies that have investigated the association between diet and cognitive development have focused on isolated micronutrients, especially n-3 polyunsaturated fatty acids (PUFA), vitamin B12, folic acid, iodine, iron and zinc. Observational studies suggest that these nutrients influence cognitive development, whereas the evidence from trials remains inconsistent (5).

In Denmark and other high-income countries, undernourishment and micronutrient deficiencies are rare. Nonetheless, Danish children's lunch and snack meals during the school day generally contain too much sugar and fat, and too little fish, vegetables, fruit, and wholegrain (6,7). In addition, about 12% do not eat any lunch and there are socioeconomic inequalities in children's dietary habits (8). The low fish intake means that the sufficiency of n-3 long-chain PUFA for cognitive development may be a relevant issue in this high-income setting. The role of iron also remains important, since iron deficiency (ID) is one of the most common micronutrient deficiencies in high-income countries (9). The European Food Safety Authority (EFSA) recently concluded that both the intake of iron, alpha-linolenic acid (ALA, 18:3n-3) and docosahexaenoic acid (DHA, 22:6n-3) are low in European infants and young children (10). However, people eat a combination of foods, not isolated nutrients; hence it is highly relevant to focus on the meal pattern, the quality of the diet and the interactive effects of nutrients. Dietary quality early in life has been positively associated with cognition later in life (11,12) and better diet quality in school aged children has been associated with improved literacy (13,14).

Nutritional interventions in the school setting have the potential to reach children from all socioeconomic backgrounds and to influence the nutritional quality of their overall diet. In low-income countries school feeding programs increase energy intake, micronutrient status, school enrolment, and attendance, and there is reasonable evidence for a positive effect on short-term cognitive functions and school performance (15). In high-income countries, the effect of school meals has only been investigated in a few studies and it remains uncertain whether diet has an effect on cognitive functions, behaviour and academic performance in school.

The present PhD thesis is based on data from the OPUS School Meal Study, in which the effects of serving healthy school meals were investigated among Danish schoolchildren in third and fourth grade. The thesis reports findings on student performance in tests of attention, reading and math. Besides this, the thesis examines whether the effect of the school meal intervention was different depending on the child's gender,

baseline reading proficiency and socioeconomic background. In relation to the effect of the intervention, the potential role of iron, n-3 LCPUFA and dietary intake was examined.

### **1.1 Objectives of the PhD thesis**

The overall aim of this thesis was to assess the effects of providing school meals for three months on cognitive function and academic performance. Specific objectives included:

- To investigate the overall intervention effects on attention, reading and math performance (Paper I)
- To examine whether an intervention effect on attention, reading and math performance was modified by the child's gender or baseline reading attainment, or by parental education level (Paper III)
- To explore the potential role of dietary intake as well as iron and n-3 LCPUFA-status in relation to effects on cognition and academic performance (Paper II and III)