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Aspects of nutritional deficits and cognitive outcomes – Triangulation across time and subject domains among students and teachers in TIMSS☆

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ABSTRACT

This article describes associations between breakfast intake and school achievements among Norwegian 9th graders in 2015 and 2019. The study involved a representative sample based on Trends in International Mathematics and Science Study (TIMSS), N = 4499 (2015) and N = 4685 (2019). This trend study using structural equation modelling and triangulation revealed a significant positive association between breakfast intake and school achievements among Norwegian 9th graders. This was found for both mathematics and science achievements, in 2015 and 2019, reported both by the students and their teachers. Mediation analyses showed that being hungry at school explained a third of the decrease in science achievement and more than half of the decrease in mathematics achievement from 2015 to 2019.

1. Introduction

A healthy diet, including regular intake of main meals such as breakfast are fundamental to health and well-being (Affinita et al., 2013). Integrating a healthy diet as part of a healthy lifestyle provide optimal circumstances for brain development and learning (Naveed et al., 2020). Further, intake of breakfast have been shown to be associated with cognitive abilities like memory (Galioto & Spitznagel, 2016). There is, however, a recurring question of whether breakfast habits are related to academic achievements, both in the research literature and in political debates and media. If academic success deteriorate because students feel hungry, the consequences could be dire both for the students themselves with regards to competition for further studies and future job markets, and for the future success of the marked economy (OECD, 2016). Further, in the future, todays knowledgeable, successful students will play an important part in addressing challenges related to sustainable development of health, technology, environment, and climate. Moreover, it could lead to inequality among students, as students who feel hungry may lag behind other students in academic success (Chzhen et al., 2018).

While there are some studies on this internationally, there is a need for new knowledge due to lack of research in a Nordic setting assessing this relationship (Burrows et al., 2017a, 2017b). Further, methodological challenges exist in current literature, such as lack of representative samples (Burrows et al., 2017a, 2017b), failing to take confounding variables like socio-economic status (SES) and ethnicity into account (Scaglioni et al., 2018), lack of longitudinal or trend studies, and weak causal inferences (Adolphus et al., 2017). Outcomes in both Norwegian and international studies rarely include academic achievements when the relation regarding breakfast intake is assessed. We address this gap in research by investing the association between intake of breakfast or being hungry when arriving in school, and school achievements among Norwegian 9th graders in 2015 and 2019. Further, we investigate whether feeling hungry when arriving at school may explain decreased achievement in mathematics and science as evidenced by Trends In Mathematics and Science Study (TIMSS) 2019 (Kaarstein et al., 2020; Mullis et al., 2020). Using triangulations (across respondents, time, and outcome), robust methodology, and representative samples at the national level, we aim to draw valid inferences to contribute to educational policy and practice.

; TIMSS, Trends in International Mathematics and Science Study.

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1.1. The Norwegian school system and factors influencing student's academic achievements

In Norway, the vast majority of the students (96%) attend public schools (Statistics Norway, 2020). The children start school the year they turn six years' old. All Norwegian children and adolescence attend mandatory school for 10 years. After that, most students choose theoretical studies preparing for university studies (3 years) or vocational training (4 years).

A large bulk of previous research investigate factors that promote student outcomes (Kyriakides et al., 2020). These factors would often be related to school factors such as school climate (Wang & Degol, 2016) teacher competence (Darling-Hammond, 2016), teacher self-efficacy and beliefs (Chong et al., 2018), and teacher's instruction (Klieme et al., 2009; Nilsen & Gustafsson, 2016). The outcomes used in such studies would most often include academic outcomes in key subjects such as mathematics (see e.g. (Kyriakides et al., 2020)). However, studies on student behavior and disposition, such as genetic disposition (Olson et al., 2014), diet (Burrows et al., 2017a, 2017b), and physical activity (Álvarez-Bueno et al., 2017), rarely relate these to academic achievement. Rather, they would use outcomes such as health, well-being and cognitive outcome such as memory and intelligence. Educational policy needs to know what factors promote student learning outcomes, especially in key subjects like mathematics. Hence, there is a need to investigate relations between student behavior and dispositions and student academic learning outcome, and among these, a fundamental factor to learning is diet (Burrows et al., 2017a, 2017b).

1.2. Trends in breakfast intake among Norwegian students the last decade

The diet of Norwegian students is on a general basis in line with the dietary recommendations, but some challenges still remain: the intake of saturated fat and added sugar is too high and the intake of fruit, vegetables and fish is too low (Hansen et al., 2015). Norwegian students do not have any national arrangements for intake of breakfast at school; hence they likely consume their breakfast at home before school hours. There are differences in breakfast intake among Norwegian students with respect to parental educational level; having parents with higher educational level has been associated with higher odds of eating breakfast (Vik et al., 2013).

Breakfast is considered an important part of a regular meal pattern, since our body needs refueling after an overnight fast. Further, it is shown that those skipping breakfast, have a lower diet quality than those having breakfast (Medin et al., 2019). Still, data on the prevalence of eating breakfast, and time trends, are somewhat uncertain in Norway as the national dietary studies have response rates of 50% (Hansen et al., 2015). In 2000, such national data showed that 89% of 4th graders and 78% of 8th graders reported to eat breakfast daily (Andersen & Øverby, 2002), while comparable numbers from 2015 are 92% of 4th and 81% of 8th, respectively (Hansen et al., 2015). More recent time trends are lacking. The Norwegian data from the international study the Health Behaviours in School-aged Children (HBSC) study, showed that approximately 65% of Norwegian 11–15-year old's consumed breakfast daily, and that there has been a moderate significant decrease in adolescents doing so from 2002 to 2010 (Lazzeri et al., 2016). The current literature shows inconsistency in numbers, still, the numbers that do not eat breakfast, 8–35%, are substantial. Studies investigating breakfast intake over time is highly needed, preferably from representative samples with high participation rates. Such studies are needed to enable stakeholders to make evidence-based health promotion and educational decisions.

1.3. Breakfast intake and school achievements

The literature presents clear relations between breakfast and health (in general) among children and adolescents (Lazzeri et al., 2016), and specifically been linked to weight status among children and adolescents (Vik et al., 2013) including in observational studies (Szajewska & Ruszczynski, 2010). However, moderate associations exist for regular breakfast consumption in relation to outcomes of academic achievements (Burrows et al., 2017a, 2017b). It is suggested that breakfast consumption may improve cognitive function related to memory, test results, and school attendance (Rampersaud et al., 2005). Further, a review of studies assessing breakfast intake showed positive and conclusive effects on cognitive performance, academic achievement, and also quality of life and well-being (Lundqvist et al., 2019). Cooper et al. suggested that breakfast consumption enhances cognitive function in an adolescent population when compared to breakfast omission (Cooper et al., 2011). Using cognitive tests, Wesnes et al. (2012) showed that students who had eaten breakfast outperformed those who had not eaten breakfast on tests of attention and memory. They proposed that breakfast may play a positive role in maintaining cognitive function, especially during the morning hours (Wesnes et al., 2012).

The literature review shows that while there are some studies investigating the effect of breakfast intake on outcomes such as health, breakfast intake in relation to academic achievements is less studied (Edefonti et al., 2014; Lundqvist et al., 2019), and few large-scale studies with representative samples have been performed (Lundqvist et al., 2019). There are several methodological challenges when studying the relation between breakfast intake and academic achievements which makes it hard to compare studies. These include study design (e.g., cross-sectional versus longitudinal) and sampling (non-random samples with regards to e.g., regional differences and home background) (Adolphus et al., 2017). Furthermore, there are issues related to the choice of objective cognitive tests, choice of objective and subjective appetite measures, providing a fixed breakfast compared with ad libitum, assessment and definition of habitual breakfast consumption, and influence of confounding variables (Adolphus et al., 2017). There is especially a need for methodological sound studies in Nordic countries, as Norway.

The current study addresses indicators of nutritional deficits such as lack of breakfast intake, lack of basic nutrition and students coming to school hungry. Further, the fact that food consumed right before and during school hours does not simply relate to public health among students but might also be relevant for academic achievements. Studies of the relation between breakfast eating and academic achievements are lacking in Norway, especially in big datasets such as TIMSS. Norway represents a rich country, and lack of food is not an issue. However, lack of time in families with a busy schedule and also the fact that autonomy among older students may lead to less breakfast consumption, may be relevant for the proposed association.

To address the current research gaps, we aim to examine students' breakfast intake by investigating:

1. Changes in breakfast routines:

a. How has students' reports on of how often they eat breakfast changed between 2015 and 2019?
b. How has teachers' perceptions of students' lacking basic nutrition changed between 2015 and 2019?

2. Relations between breakfast and academic achievement

a. What are the associations between feeling hungry when arriving in school and academic achievements in mathematics and science, in 2015 and in 2019?
b. What are the associations between teachers' perceptions of students' lack of basic nutrition and academic achievements in mathematics and science, in 2015 and in 2019?

3. To what extent may feeling hungry when arriving in school explain changes in achievement in science and mathematics from 2015 to 2019?

The reason we include both mathematics and science outcomes, students and teachers' report, and two time points, is to triangulate and thus validate our findings to provide more robust inferences.

2. Methods

2.1. Data and Sample

The present study is based on data from TIMSS 2019 and TIMSS 2015. TIMSS is an international large-scale assessment study which is repeated every fourth year. It measures students' mathematics and science competence in grade 4 and 8 (for Norway: grade 5 and 9), and includes contextual information from student, parent, teacher, and principal -questionnaires (Mullis et al., 2020).

TIMSS is a trend study, meaning that the scores on mathematics and science are comparable across time. This is done by so-called concurrent calibration, meaning that each cycle is linked (Martin et al., 2020). The mean achievement score is set to 500 with a standard deviation of 100 according to the cycle of 1995 (see e.g. Martin et al., 2020).

The present study includes representative samples at the national level of Norwegian 9th graders who participated in TIMSS 2015 (N = 4499) and 2019 (N = 4685), as well as their mathematics and science teachers. TIMSS implements a two-stage random sample design, with a sample of schools drawn as a first stage and two intact classes of students selected from each of the sampled schools as a second stage (if the school only has one class, then one class is sampled) (LaRoche et al., 2020).

Table 1 provides descriptive statistics of the samples and also shows how Norwegian students' achievements in mathematics and science decreased from 2015 to 2019. Mathematics achievement decreased by 9 points and science by 13 points.

2.2. The measures

In science, there are more than 200 items covering all content dimensions (physics, chemistry, biology, and earth science) as well as all cognitive dimensions (knowing, applying, and reasoning) (Mullis & Martin, 2017). About half the items are multiple choice, and the rest are open response items. The design is the same in mathematics, with over 200 items covering the cognitive dimension as well as the content dimension (algebra, geometry, number, data and probability). The trend items that are not publicly available and are the same from one cycle to next, constitutes about half the items. It would take the students more than 8 h to answer all the items in science and mathematics which is not feasible. Therefore, the students solved different items. A rotating matrix design was used to cover all the items. This way it only took the students approximately 30 min to respond to each subject domain. TIMSS uses item response theory (IRT) to merge all the responses and produces 5 plausible values. An imputation of these 5 plausible values is necessary to perform the analyses (Rutkowski et al., 2014a, 2014b).

The present study also includes contextual information from the student and teacher questionnaires. In the TIMSS 2019 student questionnaire, the students were asked: "How often do you feel this way when you arrive at school?". The students then rate how often they feel hungry. The response options are: "Never", "Sometimes", "Almost every day", and "Every day".

In the TIMSS 2015 student questionnaire, the students were asked how often they eat breakfast on school days with the same response options as in TIMSS 2019. Although the scale is not operationalized in the exact same way when it comes to feeling hungry, and are therefore not directly comparable, they are conceptually comparable in how skipping breakfast would make the students feel hungry when they arrive at school.

The questions in the teacher questionnaires of 2019 have not changed since 2015. The teachers were asked: "In your view, to what extent do the following limit how you teach this class?". Both the mathematics and the science teachers rated the following statement: "Students suffering from lack of basic nutrition". The response options were: "Not at all", "Some", and "A lot". Norway is a wealthy country with very few malnourished children and small difference in socio-economic status between schools (OECD, 2016). Moreover, in Norway, there is no lunch provided in the schools, hence all students bring their own lunch. However, some students may not have brought any lunch, and some students may not have eaten breakfast and arrive hungry at school. This may be observed by the teachers, and hence this is most likely the reason why teachers would think that students suffer from lack of basic nutrition.

SES, gender, and minority (non-native speakers of Norwegian) were used as control variables. SES was measured as a composite variable made by TIMSS and using Item response theory (see https://timss2019.org/reports/home-educational-resources-8/). SES is rated by students and consists of parents' education, how many books there are in the home, and number of home study supports (such as having their own room). Minority is measured by students' ratings of how often they speak Norwegian at home, with the following response options: "Never", "Sometimes", "Almost always", and "Always." The gender variable is coded 0 for girls and 1 for boys.

2.3. Methods of analyses

The data from 2015 and 2019 was merged to one SPSS file. Mplus version 8 (Muthén & Muthén, 1998–2017) was used to do a two-step structural equation modelling (SEM) analyses. SEM is an appropriate analysis method for cross sectional, nested data. Robust maximum likelihood was used to account for missing data. To take into account the hierarchical design of the data, where students are nested within classes, and classes within schools, we used the Mplus option "type = complex", where the clustering variable is IDCLASS (the unique class identification). The class weights and plausible values for mathematics and science were included according to recommended procedures (Rutkowski et al., 2014a, 2014b). In Step 1, SEM models were used to estimate the relations between the predictor (feeling hungry) and student outcomes, controlling for SES, gender, and minority. We triangulated the results in three ways when investigating the relations between breakfast and student outcomes by: 1) using both student-reported data and teacher reported data, 2) by using students' outcomes in science and mathematics, and 3) by using data from 2015 and 2019. This way we aim to ensure the reliability and validity of the results by using data based on different respondents, different outcomes, and at two different time points.

In Step 2, we used trend study path analyses (Murnane & Willett, 2011; Nilsen & Gustafsson, 2014), where we investigate whether lack of nutrition may explain changes in achievements in mathematics and science from 2015 to 2019. We do this by investigating whether the predictor mediate the effect of time on achievement (see Fig. 1).

A dummy variable for time, coded 0 for the 2015 cycle and 1 for 2019, was created. The effect of time on achievement is expected to be negative for both science and mathematics since we already know that these achievements have decreased (Mullis et al., 2020). The

Table 1
Descriptive statistics (standard error in parentheses).

	2015	2019
Number of students	4499	4685
Number of schools	150	154
Mathematics achievement	512 (2.3)	503 (2.4)
Science achievement	509 (2.8)	495 (3.1)
Percentage girls and boys	50.0% girls	49.2% girls

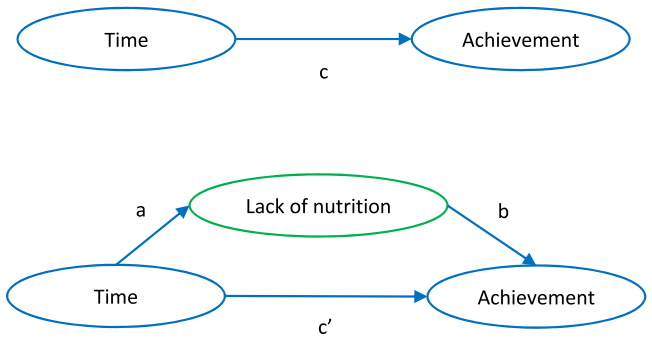

Fig. 1. Mediation model.

unstandardized regression coefficient for the effect of time on achievement (c) is expected to be around − 13 for science, and − 9 for mathematics, since this was how much the achievement scores declined in the two subjects. The effect of time on lack of nutrition (relation "a" in Fig. 1) will be negative if the problem is bigger in 2019 than in 2015. The effect of lack of nutrition on achievement will be positive if *less* lack of nutrition has a positive effect on achievement (b). The direct effect of time on achievement (c`) is expected to decrease if lack of nutrition mediates the time changes in achievement. The indirect effect of lack of nutrition (a times b, not shown in Fig. 1), reflects how many points of the decrease in achievement is explained, or mediated, by lack of nutrition. In this model, the indirect effect is the most interesting as it provides answers to our research question 3. SES, gender and minority were not included in this model, as they have not changed from 2015 to 2019 (Mullis et al., 2020; Nilsen & Gustafsson, 2014).

3. Results

3.1. Research question 1: Changes in breakfast routines from 2015 to 2019

In research question 1 we explore changes in breakfast routines from 2015 to 2019. With regards to students reports, there were 27% less students who reported *never* feeling hungry in 2019 as compared to 2015, and 27% more students rather reported that they *sometimes* feel hungry in 2019 as compared to 2015. In other words, students feeling hungry when arriving at school seems to be an increasing problem.

Teachers also reported on students' diet. As mentioned in the methods section, the teachers were asked: *In your view, to what extent do the following limit how you teach this class?* The response options for "Students suffering from lack of basic nutrition" were*: a lot, some, not at all.* The percentages from 2015 are subtracted from those of 2019. The results show that the percentages of teachers who reported that this was a problem (as indicated by the response "some" and "a lot"), increased by about 6% in science, and by about 8% in mathematics. There were fewer teachers who reported that lack of nutrition did "not at all" limit their teaching in 2019 than in 2015 (about 8% less in mathematics and 6% less in science). Taken together, the responses from the teachers and the students seem to point to a growing problem over time with students' nutrition and breakfast routines.

3.2. Research question 2: The relation of breakfast on academic achievement

The relations between the students' reports on *breakfast* (2015) and *hungry* (2019) and achievements in mathematics and science, are shown in Table 2. After controlling for SES, gender, and minority, the effect of both predictors on mathematics and science achievement are significant in both 2015 and 2019. For instance, not being hungry is associated with an increase of about 11 score points in mathematics achievement (unstandardized regression coefficient). One year of schooling in lower secondary school is about 20 score points in Norway (Kaarstein et al., 2020; Olsen & Björnsson, 2018). Hence 11 score points is more than half a year of schooling. Similar results are found for science achievement, albeit with slightly higher regression coefficients. In general, the results hence indicate that that not being hungry (or often eating breakfast) was important for student achievement in both 2015 and 2019.

Table 2
Regression of Being Hungry when arriving in school (2019) and Breakfast intake (2015) on student achievement in mathematics and science. Students' reports.

		Breakfast (2015)/ Hungry (2019)	SES	Gender	Minority
2015	**Full model**	10.48 **	42.01 **	2.65	9.48 *
	Math	(0.16)	(0.29)	(0.02)	(0.08)
	Full model	13.72 **	49.87 **	6.90 *	18.09 **
	Science	(0.18)	(0.31)	(0.04)	(0.14)
2019	**Full model**	11.02 *	48.67 **	3.06	5.68 *
	Math	(0.13)	(0.31)	(0.02)	(0.05)
	Full model	11.76 *	60.06 **	8.51 *	12.70 **
	Science	(0.12)	(0.30)	(0.05)	(0.10)

*denotes $p < 0.05$, * * denotes $p < 0.001$. Standardized regression coefficients are in parentheses

With regards to teachers' responses, the relations between lack of nutrition and student achievements in mathematics and science in 2015 and 2019, are reported in Table 3. Lack of nutrition is coded with higher values for *less* lack of nutrition.

After controlling for SES, gender and minority, the effect of *less* Lack of nutrition on student achievements in mathematics and science in 2015 and 2019 are positive and significant. For instance, low levels of Lack of nutrition are associated with an increase of about 9 score points in mathematics achievement and 11 score points in science (unstandardized regression coefficients) in 2015, which is more than half a year of schooling. Similar results are found for 2019, albeit with a slightly stronger relation in mathematics and weaker in science. In general, when using teachers' reports, the results hence indicate that nutrition was important for student achievement in 2015 and 2019, which is in line with results using students' reports.

In mathematics, the strength of the regression coefficients for all predictors increased from 2015 to 2019. In science, they decrease. Except for "Hungry" in mathematics, all of these differences are significant.

3.3. Research question 3. Trend

In research question 3 we examined to what extent the predictors (feeling hungry when arriving in school and lack of nutrition) may explain changes in achievement in science and mathematics from 2015 to 2019. The results from the trend analyses, show that before adding the predictor, the effect of time on science achievement is 13,01 score points and on mathematics 8,42 score points (unstandardized). This means that students science achievement decreased by 13 points and mathematics achievement by 8 points, which is in line with the

Table 3
Regression of Lack of nutrition on student achievements in mathematics and science. Teachers' reports.

	2019	Lack of Nutrition	SES	Gender	Minority
2015	**Full model**	8.52 *	43.64 * *	4.49	11.58 *
	Math	(0.07)	(0.31)	(0.03)	(0.10)
	Full model	11.07 *	52.42 * *	9.77 *	19.54 * *
	Science	(0.08)	(0.32)	(0.06)	(0.15)
2019	**Full model**	10.49 *	50.66 * *	5.53	4.616
	Math	(0.08)	(0.32)	(0.04)	(0.04)
	Full model	8.12 *	61.22 * *	10.83 *	11.86 *
	Science	(0.05)	(0.34)	(0.06)	(0.10)

*denotes $p < 0.05$, * * denotes $p < 0.001$. Standardized regression coefficients are in parentheses

estimates of TIMSS (Mullis et al., 2020).

In Table 4, the results from the mediation models for science and mathematics achievements are provided. In this model we examined whether the predictor may mediate the effect of time on science and mathematics achievement, or in other words, whether the predictors may explain the changes in achievement.

The results show that time has a negative effect on Breakfast (unstandardized regression coefficient is −0.26 in science and −1.22 in mathematics). This is in line with the findings of RQ1, that showed that more students were hungry at school in 2019 than in 2015. In other words, this problem has increased over the four years.

The effect of Breakfast on achievement is about 16 score points in science and 14 in mathematics, meaning that often intake of breakfast is associated with an increase in achievement. These results are in line with the results from RQ2, although the regression coefficients from the mediation models are higher. The number of students in this mediation model is also higher (due to inclusion of students from both 2015 and 2019), and this may partly explain the higher regression coefficients. However, the results from the trend study mediation models are most likely more robust than the models with the cross-sectional design as shown in Tables 2 and 3 (see Nilsen & Gustafsson, 2014).

The effect of time on science and mathematics achievement is reduced from about 13 points to about 10 points in science, and from about 8–3 points in mathematics. This means that the predictors explained part of the changes in achievement over time. The indirect effect, which is the effect that answers our research question, is about − 4 points in science, and about − 5 points in mathematics. This means that out of the 13 score points decrease in science achievement, 4 of these were mediated, or explained by Breakfast. In mathematics, 5 of the 8 points decrease in achievement were mediated by Breakfast. In other words, about one third of the decrease in science achievement and more than half of the decrease in mathematics, may be explained by students feeling more often hungry in 2019 than in 2015.

With regards to teachers' reports, time had a negative effect on lack of nutrition in both science and mathematics. This means that teachers reporting low levels of lack of nutrition decreased with time, or, in other words, teachers reported that students had a greater lack of nutrition in 2019 than in 2015. This is in line with results from RQ1.

There was a significant and positive effect of *not* lacking nutrition and achievement in both science and mathematics. Lack of nutrition explained about one and a half point of the science achievement. The indirect effect for lack of nutrition in mathematics was not significant.

4. Discussion

In this study we used data from TIMSS Norway and included 9th grade students and their teachers from both 2015 and 2019. We found that students' reports on of how often they eat breakfast at school have changed between 2015 and 2019 and have worsened in this timespan; fewer eat breakfast. The teachers' perceptions of students' lacking basic nutrition have also changed between 2015 and 2019 in line with students' perceptions/reports.

We found a significant association between the predictor: being hungry when arriving at school/breakfast skipping and school achievements in both mathematics and science among Norwegian 9th graders. These results were found both in 2015 and 2019. This was reported both by the students themselves and their teachers. Further, mediation analyses showed that being hungry when arriving at school explains as much as 4.1 out of 13 points of the decrease in science achievement and 4.7 points out of 8 points in mathematics achievement.

We triangulated the results across subjects, student and teachers' ratings, and time, and found alignments both in terms of changes from 2015 to 2019 in variables pertaining to nutrition, and the effect on achievement. The associations are still significant when adjusted for gender, SES, and minority in the analyses. We further triangulated the results using different methodology (descriptive statistics, SEM analyses for separate samples, and trend study approaches on merged samples). These methods are robust and complex, and the sample is representative. The inferences drawn are hence reliable and valid.

These results from TIMSS show that there has been a large decline in students reporting that they are never hungry when they arrive at school/eat breakfast every day. Although the results are hampered by change in wordings from 2015 to 2019, the decline from 57.6% to 30.9% from 2015 to 2019 in 9th graders reporting that they have eaten before school, is alarming. Previous Norwegian results of trends are inconsistent; however, some decline in breakfast consumption has been reported (Lazzeri et al., 2016). In addition, it is, from a public health perspective, troublesome that only 30.9% of the students report that they are never hungry when they arrive at school. When food is not consumed our physical and cognitive systems are unable to work optimally (Development Initiatives, 2017; Nyaradi et al., 2013; Spencer et al., 2017).

In the current study we wanted to explore this further, to evaluate whether being hungry or not having breakfast were associated with school achievement in both mathematics and science among Norwegian 9th graders. Our results show robust associations, indicating that not eating breakfast/feeling hungry at school, is not only physically suboptimal as is shown by others (Lazzeri et al., 2016), but also suboptimal for school achievements. This was confirmed by using data from two different time points, and by teachers' reports and its associations with student achievement as well. It is well known that lack of nutrients and also an unhealthy diet are associated with reduced cognitive development. Our findings are in line with international studies (Burrows et al., 2017a, 2017b; Florence et al., 2008; Wesnes et al., 2012) and show that in a high-income country and a well-functioning welfare state, such as Norway, children attend school without having eaten and it has consequences. Strengths of our study is the use of standardized tests from TIMSS, with representative samples and data that is subject to strict quality assurances. With such data we were able to show that those not having breakfast have lower scores in science and mathematics, equivalent with loss of half a year of schooling. There is a general focus on how to improve teaching and how to create an excellent learning environment, however, discussions of the essential meaning of food in this relation is lacking from the discussion. We suggest that sufficient energy and nutrition should be included as a basic in all discussions about learning, also in high income countries as Norway.

We further found that the reduced breakfast intake (or feeling

Table 4
Predictors (breakfast intake, lack of nutrition) mediating the effect of time changes on student achievements in science and mathematics.

	Variable	Effect of time on the variable	Effect of variable on achievement	Effect of time on achievement	Indirect effect
Science	**Breakfast**	-0.26 * *	15.53 **	-9.95 * *	-4.08 * *
		(−0.13)	(0.18)	(−0.06)	(−0.02)
	Lack nutrition	-0.07 *	19.10 **	-11.76 * *	-1.42 *
		(−0.07)	(0.12)	(−0.07)	(−0.08)
Mathematics	**Breakfast**	-1.22 * *	13.87 **	-3.06 *	-4.74 * *
		(−0.53)	(0.06)	(−0.01)	(−0.03)
	Lack nutrition	-0.01	15.27 **	-6.62 *	-0.18
		(−0.01)	(0.11)	(−0.04)	(−0.00)

*denotes $p < 0.05$, * * denotes $p < 0.001$. Standardized regression coefficients are in parentheses

hungry more often) could explain some of the change in school achievements. To our knowledge this has not been reported earlier and shows that not having breakfast/not eating has detrimental effects on school achievement and could partly explain e.g. why Norwegian students have lower scores compared to other Nordic countries (Mullis et al., 2020).

Associations between the predictor feeling hungry and school achievement, and also the explanation of negative change in subject scores, were just vaguely attenuated when adjusting for socio-economic position. It is well known that both diet and school achievement are socio-economically patterned, and one could imagine that the associations described were for the most part, due to socio-economic differences. When this is not the case, the findings are even more clear, pointing to the need to address diet in all groups of students, not only socially disadvantaged.

4.1. Limitations

TIMSS is a cross-sectional study and thereby causality cannot be inferred. However, there are causal methods that can be used to enhance the level of possible causality (Gustafsson, 2013). We used such an approach to explain time changes in achievement. Furthermore, we also validated our findings by triangulating across subject domains, time points and student and teachers' ratings.

The item of breakfast was phrased differently in 2015 and 2019, but it basically measures the same concept. This measure is hence a limitation by the study. However, using different methods, and both teacher and student ratings, all results arrive at the same conclusion.

To identify causal relations between feeling hungry and school achievement, a randomized controlled trial would be the preferred design. However, this is not ethical and therefore our results with the strengths mentioned above, is the best available design.

Future studies may want to deepen the knowledge by including a larger set of questions on nutrition.

4.2. Implications for practice and policy

The decline in science scores among students in lower secondary school has received attention from media and policy in Norway (Frøjd & Heie, 2020). There was not only a negative development over time, but their scores were also worse than their other Nordic counterparts', as much as one year behind Swedish and two years behind Finnish students. These differences have until now been explained by fewer hours of instruction in science compared to other Nordic countries (Kaarstein et al., 2020) and national leaders search for ways to improve this. Our results show that for both mathematics and science, an increased feeling of being hungry at school may explain some of the negative development. As much as half a year of schooling in mathematics and science can be explained by being hungry when arriving in school. Over time such differences can have detrimental impacts on Norwegian students' competence and capacity. Our results call for action from both the educational system and health system, and political will to address these issues. Feeling hungry are factors in the private sphere, with parental responsibility, however, our results show that it affects the learning capacity of Norwegian students and should therefore be discussed also outside the private sphere. It is up to the politicians how these issues can be solved, structural interventions, like school breakfast, including the importance of food in teacher educations, or individual interventions like informing parents, teachers, and school leaders, could be suggestions for actions.

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CRediT authorship contribution statement

Frøydis Nordgård Vik: Conceptualization, Writing – original draft, Writing – review & editing. **Trude Nilsen:** Methodology, Software, Validation, Formal analysis, Data curation, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Nina Cecilie Øverby:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

No competing interest.

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