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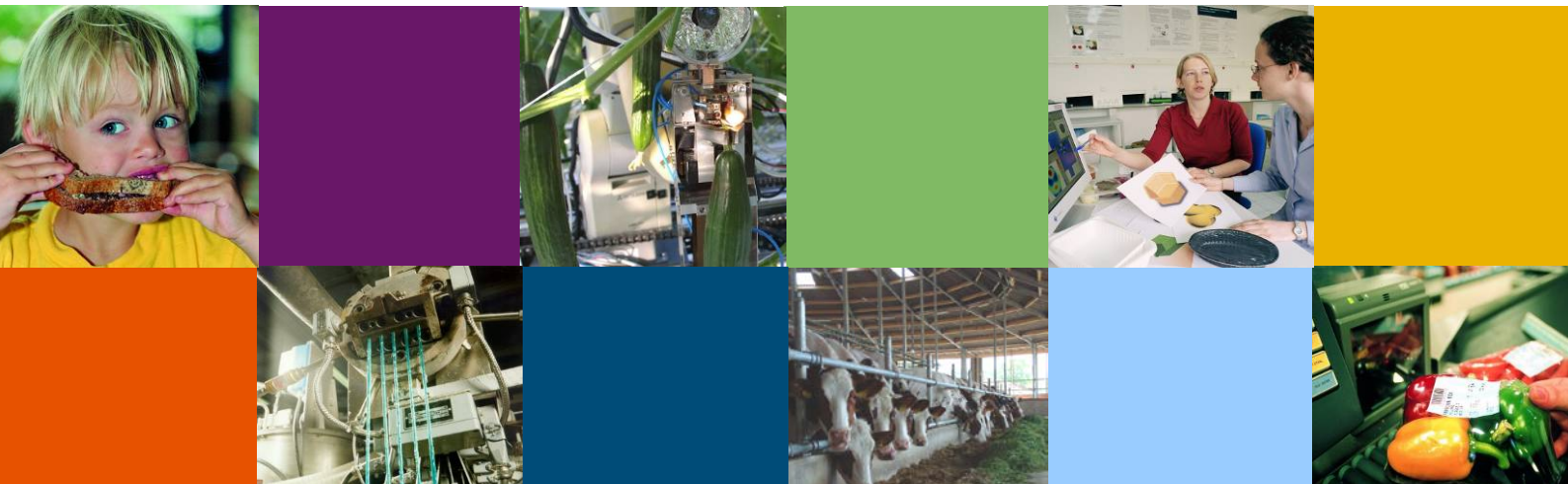
Literature overview: Breakfast benefits for children and adolescents

Monique Vingerhoeds

Report 1564



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Title	Literature overview breakfast benefits for children and adolescents
Author(s)	Monique Vingerhoeds
Number	1564
ISBN-number	978-94-6257-515-8
Date of publication	April 14, 2015
Confidentiality	No
OPD code	
Approved by	Judith van der Horst

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Abstract

There is a lot of scientific interest in the role of breakfast in dietary quality and overweight prevention and in the effect of breakfast on cognitive and mental functioning. This literature review aimed to give some insight in the benefits of breakfast for children and adolescents, with a focus on overweight, food intake and cognition. In addition, we explored the magnitude of skipping breakfast in the Netherlands and factors associated with this behaviour.

Different factors are related to breakfast skipping, including age (older children more likely skip breakfast), gender (girls skip breakfast more often than boys), whether parents have breakfast (positive effect), cultural habits, the socioeconomic status (children from lower socioeconomic backgrounds tend to skip breakfast more often) and chronotype (adolescent breakfast skippers were more often evening chronotypes).
The degree of breakfast skipping in the Netherlands is not completely clear. Recent reported numbers of children and adolescents not having a daily breakfast range from 3% to 16% for 4-11 year olds and 16% to 20% for 12-18 year olds.

Main conclusions from the literature survey are:

- Regular breakfast consumption is not associated with lower energy intake over the day.
- The majority of the literature confirms that breakfast consumption can prevent children and adolescents to become overweight or obese. Timing of energy intake and meal frequency seem relevant factors for body mass index (BMI).
- Having breakfast improves cognitive functioning in children and adolescents.

In conclusion, because of the benefits of breakfast on weight and cognition, children and adolescents should be stimulated to have breakfast.

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1 Introduction

Breakfast, the first meal of the day, is often mentioned as the most important meal of the day. A well-known old adage is: "Breakfast like a king, lunch like a prince, and dine like a pauper". Is there wisdom in this old saying?

Figure 1: Breakfast like a king[1]

People have strong beliefs about the benefits of either having breakfast or skipping it. For example, "breakfast is a good start of the day". Or, "skipping breakfast helps me to loose weight". In this overview, evidence is gathered to evaluate whether the following statements are supported by scientific literature:

1. Breakfast consumption can prevent children and adolescents to become overweight or obese
2. Breakfast consumption is associated with lower energy intake over the day
3. Breakfast consumption improves cognitive function in children and adolescents

[1] *Illustration Irene Mulder, LGB Produkties, http://www.irenemulder.nl/*

2 Breakfast habits and nutritional benefits

Timlin et al defined breakfast as the first meal of the day, eaten before or at the start of daily activities, within 2 h of waking, typically no later than 10:00 in the morning, and of an energy level between 20% and 35% of total daily energy needs (1). Breakfast consumption significantly contributes to whole diet nutrient adequacy and is often referred to as the most important meal of the day, yet many individuals skip breakfast (2, 3). In a study analysing risk factors for overweight and obesity among 25,000 Dutch secondary school students (13-14 and 15-16 year) it was shown that, compared to alcohol consumption and physical inactivity, breakfast skipping is the most important risk factor for overweight and obesity (4).
This paragraph briefly summarizes the nutritional benefits of having breakfast, followed by indications of the frequency of breakfast skipping and factors contributing to this skipping.

2.1 Nutritional benefits is breakfast

Breakfast plays a key role in helping adults and children to meet nutritional recommendations, especially because of its contribution to intake of whole-grains, milk and milk products, and fruit. Rampersaud et al (2005) examined the association between breakfast consumption and several health-related factors such as nutritional adequacy in children and adolescents (5). They found that breakfast eaters have higher daily intakes of fibre, calcium, vitamin A, vitamin C, riboflavin, zinc, and iron and are more likely to meet nutrient intake recommendations compared to breakfast skippers. Thus breakfast consumers are more likely to have better overall diet quality, and better intake of micronutrients, macronutrients, and fibres (5). In line with this, eating breakfast may offer benefits for cardiovascular, digestive, and bone health (6).

2.2 Frequency of breakfast skipping

A review paper published in 2005 showed that breakfast skipping is highly prevalent in the United States and Europe (10% to 30%) (5). The variation in the reported values may be related to differences in age group, population, but also on the definition of breakfast skipping used in different studies (5). For example, skipping breakfast can be defined as missing at least one breakfast per week, but also as one breakfast on a school day, or as skipping breakfast more often per week. Often no explanation is given why a particular definition was chosen (7). Also selective non-responses can influence the reported degree of breakfast skipping (8). Different Dutch studies are available on breakfast frequency in the Netherlands. The reports show some variation in the results.

2.2.1 Children

A TNO study showed that, according to the parents, 97.0% of the 4-11 year old children had breakfast every day in 2013. This is an increase compared to 2010, where 93.9% of children in this age group had a daily breakfast (9). Self-reported breakfast frequency by Dutch children from

grade 6 to 8 of primary schools (age about 9-12) showed that 84.6% of the children have a daily breakfast, and another 9.5% have breakfast almost every day (5 to 6 times per week) (10). The most probable causes for this difference in the results is the age difference and that parents may have another viewpoint on breakfast definition and habits than children.

2.2.2 Adolescents

Studies in adolescents are mostly done with self-reported answers, making these studies easier to compare, although the sample (e.g. variation in socioeconomic status, ethnicity, sample size) and the way of asking for breakfast habits may have influenced the results. A higher percentage of breakfast skippers was reported among adolescents compared to younger children, as breakfast skipping increased during the transition to adulthood (5, 8, 9, 11).

When focusing on the Netherlands, a few studies have been done. A study published in 2002 showed the percentage of adolescents (12-18 year) not having a daily breakfast was 39.7% (8). A study run in 2006 showed that young adolescents (13-14 year) skipped breakfast less often (29.3%) than 15-16 year old adolescents (39.2%) (4). In 2012 Boschloo et al reported a study among 605 adolescents (11-18 year), showing 2.5% skipped breakfast on all school days and 14.0% skipped breakfast on some, but not all, days of the school week (12). This adds up to 16.5% breakfast skippers. Recently, slightly lower breakfast frequencies were reported by TNO for adolescents (12-18 year), i.e. 80.2% had a daily breakfast in 2013 (19.8% breakfast skipping) and 83.9% in 2011 (16.1% breakfast skipping) (9). So, the recent studies show that 16 to 20% of the Dutch adolescents do not have a daily breakfast, which is an improvement compared to the results from the measurements of 2002 and 2006.

2.3 Factors influencing breakfast skipping

Several factors influence breakfast skipping, including age, gender, whether parents have breakfast, cultural habits, the socioeconomic status (SES) and chronotype. The factor age was discussed above. With respect to a gender effect, it was reported that girls, both children and adolescents, skip breakfast more often than boys (4, 5, 13, 14).

Parental breakfast eating and living in two-parent families were positively associated with adolescent's breakfast consumption (3). The positive association between parental eating behaviours and those of adolescents suggests that parents are clearly playing an important role in the dietary behaviours of their children, therefore offering a potentially useful avenue for intervention (3).

A Dutch study done at the beginning of this century has shown that cultural background also affects breakfast behaviour (8). It was shown that, after correction for the year in which measurements were done and social demographic variables, especially Turkish children are less inclined to having breakfast compared to Dutch children. Being of non-Dutch origin was found to be positively associated with breakfast skipping among adolescents (14).

Having breakfast seems to be associated with the degree of education (14) and SES. Children from lower socioeconomic backgrounds more often skip breakfast (5, 8), although this is not confirmed by all studies (3). Moore et al studied the associations between deprivation (in this context pointing low SES and not being able to provide sufficient amounts and/or quality of food), attitudes towards eating breakfast and breakfast eating behaviours in 9–11-year-olds in the UK (15). They found that deprivation is associated with adverse breakfast eating behaviours both in terms of breakfast skipping and the quality of breakfasts consumed. Furthermore, low SES was found to contribute to high body mass index (BMI) mediated by the low nutritional quality of breakfast (16).

Skipping breakfast also seems to be related to people's chronotype. Chronotype is the natural preference for activity in the morning or in the evening (being a "morning person" or a "night person"). Recently it was shown that adolescent breakfast skippers were more often evening chronotypes (12). Possibly, adolescents with an evening chronotype, eat more late in the evening, want to sleep longer and/or are not yet hungry in the early morning. This is not further studied in this review, as it is outside the scope of the current report.

The main reasons given by adolescents for not having breakfast are that they are not hungry or do not have time for breakfast (17). Clearly, many factors affect whether people are having a daily breakfast, implying that interventions to improve breakfast behaviour can be targeted at various aspects.

3 Relationship between breakfast consumption, food intake and weight

Breakfast consumption and meal frequencies have been related to the risk of obesity or high body mass index (BMI) (18-20). However, the conclusions drawn from studies seem contradictory in some cases. This paragraph discusses the relation between breakfast and BMI, the role of life style in breakfast behaviour, breakfast type, and the relation between breakfast consumption and daily food intake.

3.1 Studies on breakfast and weight or BMI

The relationship between eating breakfast and BMI has never been clearly established although evidence suggests that breakfast consumption lowers the risk of obesity or a high BMI. This paragraph shows some results from US and European (Finland and Greece) studies aiming to relate breakfast habits or meal patterns of children and adolescents to BMI.

In 2003, a US study was published that examined skipping breakfast and weight change in more than 14,000 children/adolescents (9-14 year) over a period of three years (21). Skipping breakfast was associated with overweight. However, when comparing overweight children who never ate breakfast to overweight children who ate breakfast nearly every day, it was found that breakfast skippers lost BMI over the following year. This was different for normal weight children, as normal weight children who never ate breakfast gained weight relative to peers who ate breakfast nearly every day. The implications of these findings are unclear.

In the United States, children can participate in School Breakfast- and School Lunch Programs. In a study including 2228 students from grades 1 to 12 (approximately 6-17 year), it was shown that school breakfast participation was associated with significantly lower BMI, particularly among non-Hispanic, Caucasian students (22). No relationship was found between school lunch participation and BMI. It was concluded that School Breakfast Program participation may be a protective factor, by encouraging students to consume breakfast more regularly.

These results are in line with a study on cross-sectional and prospective associations between breakfast frequency and weight gain in male and female adolescents in the US (23). It was shown that the frequency of eating breakfast was inversely associated with BMI and weight gain. In addition, dieting and weight-control behaviours were inversely associated with frequency of breakfast consumption, suggesting that adolescents may resort to unhealthy eating habits (i.e., skipping breakfast) in an effort to control body weight.

In 2013, the results of a study amongst adolescents based on clinical examination and self-administered questionnaires in Finland was published (24). It was shown that a regular meal pattern of five meals per day on weekdays, i.e. breakfast, lunch, snack, dinner and an evening snack, was robustly associated with reduced risks of overweight/obesity of 16-year old boys and girls. The authors concluded that a regular meal pattern of five meals per day can help to protect against excess weight (24).

It is of interest to note that there may be a gender effect on the association between having breakfast and BMI. In a study amongst 16-year old Finish adolescents and 18-year old Greek

adolescents it was shown that daily breakfast consumption was associated with lower levels of overweight/obesity among Finnish and Greek boys, but not among girls (25). An Australian study found a gender effect of breakfast size related to BMI in adults (26): The reported amount consumed at breakfast was one of several eating habits that predicted BMI for men but not for women. Men's BMI decreased as the reported breakfast amount increased. Possibly, for boys breakfast is more important in relation to overweight/obesity and BMI than for girls.
A study in a specific group of people, namely teens after giving birth, examined the relation between breakfast consumption and snack and beverage intake and BMI. This study showed that teens from this group who ate breakfast 6 to 7 days per week had a lower BMI compared to those who ate breakfast fewer than 2 days per week. In addition, consumption of fruit, vegetables, milk, water, and cereal as a snack were higher among regular breakfast consumers in this study (27).

3.2 Breakfast consumption increases overall energy intake

The question is, how to interpret findings that people who skip breakfast either have a higher BMI or gain weight at a greater rate than people who regularly eat breakfast. It seems equally plausible to interpret these results as indicating that a high BMI causes one to skip breakfast as it is to suggest that skipping breakfast causes an increased BMI (28). In this respect, it is interesting to look at the relation between breakfast consumption and food intake.
A number of studies show that breakfast consumption influences total daily food intakes by actually increasing energy intake. For example, children who reported that they never eat breakfast had lower energy intakes than those who eat breakfast nearly every day (21).
Reeves et al. recently reported a study where adult participants (four groups based on BMI (<25 or >25 kg/m^2) and breakfast habits (breakfast omitters and eaters)) were requested to eat breakfast for an entire week, and then following a washout period, omit breakfast for an entire week, or vice versa (29). The participants reported in food diaries what was consumed and the timing of consumption. Overall more energy was consumed during the breakfast week compared to the no-breakfast week. Energy compensation after skipping breakfast occurred partly during lunch and later in the afternoon. The observation that the total energy intake during the day was lower after skipping breakfast, suggests incomplete compensation for the missed calories by skipping breakfast. This is in line with a study of Astbury et al showing that missing breakfast causes metabolic and hormonal differences in the responses to foods consumed later in the morning as well as differences in subjective appetite and a compensatory increase in energy intake (30).
The role of breakfast habits, i.e. being used to having or to skipping breakfast, also appears to affect food intake: Later in the evening breakfast omitters consumed more than did breakfast eaters (29). In the early evening, overweight participants consumed greater amounts of energy than normal weight participants. Reeves et al. conclude that the timing of food intake and habitual breakfast eating behaviour are important factors when investigating why breakfast consumption may be associated with BMI. Omitting breakfast per se does not necessarily result

in increased daily energy intakes, and may actually be associated with lower overall daily energy intakes (29).
The results of two studies of Levitsky et al were largely in line with the study described above (28). In these studies food intake was not measured by self-reporting, but food intake was measured by weighing all foods selected for a meal and left overs. Also hunger ratings were scored. A first study, focussing on compensation for food intake at lunch after skipping breakfast or having a fixed breakfast of 335 kcals, revealed that the lunch intake was similar on all occasions, despite the increased hunger ratings after skipping breakfast. In a second study it was shown that skipping breakfast compared to an ad libitum breakfast resulted in increased hunger ratings and intake at lunch. However, the increased intake (144 kcals) did not compensate for the skipped breakfast (average intake 624 kcals). Consequently, total daily energy intake was reduced by skipping breakfast (28).
Summarising, there seems to be sufficient evidence that breakfast consumption increases, rather than decreases daily energy intake.

3.3 Breakfast as a proxy for a healthy lifestyle

Lifestyle may be an important factor in the relation to breakfast consumption. In the UK it was recently shown that breakfasting frequency correlated with conscientiousness, wellbeing, age and general health, although there was no significant correlation with BMI (19). This study supports the view that breakfast eating is likely to be a proxy-variable[2] for a healthy lifestyle. In line with this, breakfast skippers may be less likely to engage in physical activity, which may contribute to positive energy balance and weight gain (5).
With respect to lifestyle it can also be mentioned that the consumption of breakfast was significantly positively associated with consumption of cereals, bread, fruit, and spreads, while coffee consumption was significantly associated with smaller breakfasts or breakfast skipping (26). Breakfast cereal consumption may be a marker of an overall healthy lifestyle (31).

3.4 Breakfast type: cereal consumption and intake

Breakfast type is an important factor in the relation between breakfast consumption and BMI. For example, breakfast cereal consumption was associated with a desirable macronutrient profile for preventing obesity and predicted weight status in women (31). Two recent reviews showed that breakfast cereal consumption was associated with a lower BMI, and less risk of being overweight or obese (32, 33). Although energy intakes tended to be higher in children and adolescents who consume breakfast cereals regularly, the prevalence and risk of overweight was lower (33). Also a study among 10-12 year old Greek children showed the important role of cereal consumption for breakfast as a part of a daily diet, in helping to maintain normal weight

[2] *A proxy variable is a variable that is used to measure an unobservable quantity of interest. Proxy variables are extremely important to and frequently used in the social sciences because of the difficulty or impossibility of obtaining measures of the quantities of interest (http://srmo.sagepub.com/view/the-sage-encyclopedia-of-social-science-research-methods/n768.xml).*

and promote a simple healthy lifestyle pattern (34). In another study with 12-17 year old Greek boys and girls it was shown that consumption of breakfast cereals was associated with lower BMI levels and a lower likelihood of overweight/obesity (13). The authors suggest that it could be of benefit to include breakfast cereal consumption in campaigns for obesity prevention, especially in children.
Recently a review was published on the benefits of breakfast cereal consumption (32). With respect to energy intake the main outcome of the review was that breakfast cereal consumption is not associated with increased intakes of total daily energy. Regular breakfast cereal consumers have (32):

- higher intakes of carbohydrate;
- higher intakes of dietary fibres;
- higher intakes of total sugars;
- lower intakes of fat;
- lower cholesterol intakes;
- enhanced micronutrient intakes;
- higher milk intakes;
- greater likelihood of meeting micronutrient recommended intakes;
- improved nutritional status;
- lower serum cholesterol concentrations.

In a large study among US adults it was shown that breakfast skippers and fruit/vegetable eaters had the lowest daily energy intake (35). However subjects who ate breakfast cereals or quick breads for breakfast had a significantly lower BMI. Eating cereal (ready-to-eat or cooked cereal) or quick breads for breakfast is associated with significantly lower BMI compared to skipping breakfast or eating meats and/or eggs for breakfast. The authors conclude that skipping breakfast is not an effective way to manage weight.

3.5 Daily rhythm and timing of food intake

Some studies have shown that even when energy intakes are similar during the day, people who consume more of those calories later in the day tend to put on more weight or loose less weight when following a diet (36). A plausible explanation is that the energy consumed in the morning is better used than energy consumed in the evening.
Recently it was shown the presence of an active circadian clock in different organs related to food intake, i.e. the stomach, intestine, pancreas or liver (18), suggesting that weight loss strategies should consider not only the caloric intake and macronutrient distribution but also the timing of food. In line with this, a French study with children aged 7–12 years showed there were no differences in energy intake over the day between groups with different BMIs. However, there were differences in the timing and distribution of the food intakes. Obese children generally ate less at breakfast and more at dinner than leaner children and consumed a greater proportion of their energy as fat at lunch and dinner (37).

The daily rhythm and the observation that timing of food intake relates to being overweight, stresses the relevance of having breakfast.

3.6 Possible explanations for contradicting results

The contradicting results in studies on the association between breakfast skipping and BMI or risk of being overweight can be explained by several factors, including definitions (5, 7). First, different studies have used different definitions of breakfast skipping (see also page 7). Second, some studies have examined BMI, but other studies have examined overweight/obesity. Third, some studies have controlled for potential confounders, but other studies have not. Dialektakou and Vranas found that fewer breakfast-skipping variables were associated with BMI than with overweight/obesity (7) Overweight or obesity (yes or no) was in this study determined by using the age- and sex-specific BMI cut-off points. Also, fewer associations were found when controlling for potential confounders than when not controlling for them. Lastly, fewer associations were found for variables corresponding to some definitions of breakfast skipping than for variables corresponding to other definitions.

3.7 Conclusion

In conclusion, although total food intake is in most reported studies higher for people having breakfast, there seems to be sufficient evidence that having breakfast contributes to a lower BMI, a lower prevalence of overweight and obesity and a more healthy nutritional status.

4 Breakfast consumption and cognitive functioning

Numerous papers have been published on the relationship between breakfast and cognitive functioning (5, 38-42). Cognition includes all mental abilities and processes related to knowledge: attention, memory and working memory, judgement and evaluation, reasoning and "computation", problem solving and decision making, comprehension and production of language, etc. This paragraph elaborates on the relation between having breakfast and cognitive functioning, including the role of the glycaemic load, as glucose is essential for cognitive functioning.

4.1 Methods to measure cognitive functioning

A range of methods exist to measure different aspects of cognitive functioning. Methods used in the literature described in this review are briefly explained below.

4.1.1 Stroop test

The Stroop test measures the sensitivity to interference in the reaction time of a task. When the name of a colour is printed in a colour denoted by the name, naming the colour of the word is faster and is less prone to errors than when the colour of the ink does not match the name of the colour (Figure 2).

Figure 2: Example of the Stroop test[3][4]

4.1.2 Sternberg paradigm

The Sternberg paradigm measures working memory and involves learning sets of stimuli containing different numbers of digits[5]. The subject is then presented with one probe stimulus at a time (a digit of 0-9) and has to indicate whether or not it was a member of the original set.

[3] *https://vivid-hypnotherapy.co.uk*
[4] *http://en.wikipedia.org/wiki/Stroop_effect*
[5] *http://anvita.info/wiki/Sternberg_Paradigm*

4.1.3 Visuospatial memory

Visuospatial memory can be examined by three subtests from the LGT-3 test (Lern- und Gedächtnistest, i.e. Learning and Memory Test-3, described by Bäumler in 1974 (43). Each test has a learning phase and a retrieval phase and are briefly explained below (38).

1. Trail subtest: subjects must memorize a route on a street map. Retrieval phase: the subjects are presented with the map only and are asked to fill in the trail.
2. Objects subtest: 20 simple drawings of objects, such as a ball, are presented. Retrieval phase: the remembered objects must be named.
3. Logos subtest: 20 logo-like figures, each consisting of a central icon and a frame, are presented. Retrieval phase: each of the central icons is presented with the choice of 4 similar frames, and the subjects must identify the frame presented with the specific icon during the learning phase.

4.1.4 Visual search test

The visual search test [29] is a perceptual task requiring attention and provides a measure of complex visual processing. The visual search uses reaction time in order to measure the time taken to detect the target amongst its distractors. An example of this could be a green triangle (target) amongst a set of red circles (distractors). Next to timing, also accuracy is measured.

4.2 Breakfast and cognitive functioning

In 2009, Hoyland et al published a systematic review on the effect of breakfast on the cognitive performance in children and adolescents (40). The main conclusions from this review were:

- Breakfast consumption is more beneficial for cognitive performance than skipping breakfast. This effect is more apparent in children with a poor nutritional status
- Benefits of breakfast consumption were most evident for measures of memory and for number of errors on attention tasks especially later in the morning
- Little research has been done comparing various breakfast types with respect to children's cognitive function, making it difficult to define recommendations for the size and composition of an optimal breakfast for children.
- Few studies examined adolescents.
- Studies of school breakfast programmes suggest that such interventions can have positive effects on academic performance, but this may be in part explained by the increased school attendance that programmes encourage.

An interesting remark was made in the review: Performance on many of the cognitive tasks is evaluated in terms of accuracy scores. Little consideration is given to motivation and effort including the ability to sustain performance over time. However, breakfast consumption might facilitate motivation and reduce the underlying 'maintenance costs' of sustained performance. Sustaining concentration and retaining information are cognitive processes of key importance for educational achievement (40).

Because of the high quality of the review by Hoyland et al, who retrieved mainly studies on children, focus here will be on adolescents and studies published after 2009.

Most studies have been done with children aged 8 to 11 years. As adolescents skip breakfast more often than younger children, and because of the greater complexity of their work, it is of interest to look at the effect of breakfast in this target population as well (39).
A study among high school students (13-20 years) has demonstrated positive short-term effects of having a standardized breakfast on cognitive functioning and self-reported alertness (38). Breakfast had no effect on sustained attention. However, male students showed improved visuospatial memory and reported feeling more positive after consuming breakfast.
Cooper et al. studied the effect of breakfast consumption on cognitive function, mood and blood glucose concentration in 96 adolescent schoolchildren (12-15 years) (39). Their work suggests that adolescent's breakfast consumption enhances the accuracy in cognitive function tests, especially the more cognitively demanding tasks, when compared to breakfast omission. This was based on a high accuracy on the more complex level of the visual search test, improved maintenance of the accuracy of the Stroop test over the morning and quicker responses on the Sternberg paradigm later in the morning after having breakfast.

The above mentioned studies evaluate short term effects of having breakfast and cognitive functioning. However, having breakfast is a habit which is also likely to affect long-term cognitive performance. Recently a Dutch study among adolescents has shown that breakfast skipping and school performance are related, i.e. breakfast skippers performed less well at school than breakfast eaters (12). These findings were similar for younger and older adolescents and for boys and girls. Breakfast skippers reported more attention problems, and attention problems were also related to school performance. Attention partially mediated the relation between breakfast skipping and school performance. The authors concluded that breakfast seems to be important for school performance, although no causal relationships can be inferred from this study.

4.3 Role of glucose, glycaemic index (GI) and glycaemic load (GL) of the meal

A small preliminary study with obese children in Italy (10 children; average age 9.6 year), showed that skipping breakfast reduced attention and visual memory performance, but had no effect on verbal memory (41). No association of cognitive functioning with hormones or metabolic changes was found except for an association of attention with carbohydrate oxidation. This observation is of interest with respect to glucose from carbohydrates. Glucose is crucial for cognitive functioning, especially for the activity of the frontal lobe (39). Research suggests that higher blood glucose concentrations are correlated with improved memory, faster information processing, better word recall, and improved performance on the Stroop test (39, 44-46). In addition it is suggested that blood glucose, which is increased after having breakfast (39), is part of the biological mechanisms through which breakfast influences performance (40).

This paragraph addresses the role of glucose, including glycaemic loads of the breakfast, on cognitive functioning,.

4.3.1 Glucose requirement

The glucose requirement in the brain varies with age. There is a rise in the rates of glucose utilization in the brain from birth until about age 4 years, at which time the child's cerebral cortex uses over twice as much glucose as that of adults (47). From age 4 to 10 years, these very high rates of glucose consumption are maintained, followed by a gradual decline of glucose metabolic rates to reach adult values by age 16-18 years (47). This high glucose utilization and corresponding glucose requirement affects, amongst others, appetite.

4.3.2 Glycaemic index and glycaemic load

Some carbohydrate-containing foods cause the blood glucose level to rise rapidly; others have a more gradual effect. The glycaemic index (GI) is a measure of the rate at which blood glucose levels are increased and maintained (48). Foods with high GI values raise blood glucose rapidly, followed by a corresponding rapid decrease. After intake of a low GI food there is a relatively smaller rise in blood glucose followed by a more stable blood glucose concentration.
To determine the GI of a meal, the contribution of each meal component has to be taken into account, since different carbohydrates contribute differently to the overall GI. To calculate the GI of a meal the total amount of carbohydrates (in grams) in a meal has to be determined. Subsequently the proportion of carbohydrates of each of the meal components contributing to the total amount of carbohydrates is calculated. This proportion is then multiplied by the predetermined GI of that component, which can be found in online GI databases. Finally the total GI of the meal is calculated by adding up the contributions from all meal components.
The glycaemic load (GL) is a number that estimates how much a food will raise a person's blood glucose level after eating it. One unit of GL approximates to the effect of consuming one gram of glucose. GL can be calculated by multiplying the amount of available carbohydrate in a food item by the GI of the food and dividing this by 100 (40).

4.3.3 Mixed results

Different studies examined the role of GI or GL of breakfast on cognitive functioning, with different results. In a study with 19 children (6-7 year) Benton et al compared the effect of breakfast consumption of a low, medium and high GL breakfast (49). The different breakfasts had a comparable energy content but differed in macronutrient composition, where the low GL breakfast had higher protein and fat contents and a lower amount of carbohydrates. It was shown that two to three hours after the low GL breakfast had been consumed, performance on the tests of memory and the ability to sustain attention were better, fewer signs of frustration were displayed and initially more time was spent on task when working individually in class (49).

The results from Ingwersen et al, examining in 64 children (6-11 year) whether the GI of breakfast cereal affects attention and memory, were more complex (48). Following the consumption of a low GI breakfast cereal compared to a high GI breakfast cereal, there was significantly less decline in children's performance on accuracy of attention (ability to sustain attention) and secondary memory (ability to store, hold and retrieve information) throughout the morning. However, no effects were found on other cognitive functions examined. It was noted that the low and high GI breakfast didn't only differ in GI, but also in composition (e.g. protein content). The authors suggest that high and low GI meals may differentially affect cognitive functions in children.

In 2014, Edefonti et al reviewed the effect of energy intake at breakfast and breakfast composition on cognitive and academic performance (42). They pointed out that there are not enough studies done and there is insufficient consistency among studies to draw firm conclusions. The hypothesis of a better and more sustained performance with a breakfast providing >20% daily energy intake still needs substantiation. However, there does appear to be emerging evidence that a lower glycaemic response after a meal is beneficial to cognitive performance. It remains unclear whether this effect is specifically due to GI, GL, to both, or to other effects unrelated to glycaemic response (42).

A recent review on influence of GI of meals (with no focus on breakfast) on cognitive functioning also concluded that findings reported in literature were inconsistent (50). Some studies showed positive effects on cognitive functioning either for the high-GI or the low-GI meal. Others did not find any differences in cognitive performance between the two meals, whereas some studies showed a positive or negative effect on performance for specific cognitive domains after consumption of one of the two meals. A low-GI meal may favour cognitive functioning, but at present the findings are inconclusive (50).

4.3.4 Combining breakfast and exercising

Recently, a paper was published on the combined effects of breakfast GI and 10 minutes mid-morning exercise on cognition in 42 adolescents (12.4±0.5 years) (51). The effects measured by the Stroop test as well as the Sternberg paradigm showed improved response rates after having a low GI breakfast, for the Stroop test especially in combination with exercise. A high GI breakfast improved response times on the Stroop test only without exercising and response times on the Sternberg paradigm only with exercising. As the effects of breakfast GI and mid-morning exercising seem to differ for the cognitive function being measured, more work is required to be able to give advice on low or high GI breakfast.

4.4 Discussion and concluding remarks

In most studies the acute effects of having breakfast on cognitive functioning have been measured showing that breakfast consumption improves cognitive functioning in children and adolescents. The studies on the effect of the glycaemic load or glycaemic index of breakfast on

cognitive functioning show mixed results both on whether there is an effect at all, and what specific cognitive tasks are affected. More research is needed to get a better insight.
In the long term, breakfast consumption may lead to beneficial physiological changes in nutrient status. Therefore Hoyland suggested that the positive effects of breakfast on cognitive performance may be the product of better nutritional profiles rather than transient changes in blood parameters (40).

5 Discussion and conclusions

This literature review aimed to give some insight in the benefits of breakfast for children and adolescents. Different factors are related to breakfast skipping, including age, gender, whether parents have breakfast, cultural habits, the socioeconomic status and chronotype. The degree of breakfast skipping in the Netherlands is not completely clear. Recently reported numbers of children and adolescents not having a daily breakfast range from 3% to 16% for 4 to 11 year olds and 16% to 20% for 12-18 year olds. The differences in percentages appear to relate to the definition of breakfast skipping, the method of measuring breakfast skipping, the year the study was done, and observed non-responses by specific target groups (e.g. specific ethnic groups had a lower response rate on questionnaires).

Three hypotheses were examined by reviewing scientific literature and are discussed below.

5.1 Breakfast consumption can prevent children and adolescents to become overweight or obese

Most studies confirm that breakfast consumption lowers the risk on obesity or a high BMI. An interesting point that came up is that lifestyle may be an important factor in relation to breakfast: breakfast eating is likely to be a proxy-variable for a healthy lifestyle. Both meal frequencies and timing of the meals are related with BMI. However, there were differences in the timing, distribution, and composition of the food intakes. Obese children generally ate less at breakfast and more at dinner than leaner children and consumed a greater proportion of their energy as fat at lunch and dinner.

The statement that breakfast consumption can prevent children and adolescents to become overweight or obese seems to be valid.

5.2 Breakfast consumption is associated with lower energy intake over the day

The finding that people who skip breakfast have a higher BMI than people who regularly eat breakfast can be interpreted in different ways: it is equally plausible that a high BMI causes one to skip breakfast as it is to suggest that skipping breakfast causes an increased BMI. Therefore it is important to examine the effect of breakfast consumption on total daily energy intake.

Most studies show that breakfast consumption increases energy intake. Skipping breakfast is only partly compensated by increased energy intake later during the day. Furthermore it appears that people eating more in the evening have a higher BMI than people with the same total energy intake that eat more in the morning and less in the evening. This stresses the relevance of timing and meal frequency, and taking into account people's chronotype.

The statement that breakfast consumption is associated with lower energy intake over the day is not confirmed. On the contrary, it seems to be related with higher energy intake.

5.3 Breakfast consumption improves cognitive function in children and adolescents

There is sufficient evidence that breakfast consumption improves cognitive functioning in children and adolescents.

The main discussion on cognitive function and breakfast is about the meal composition (GI, GL, macronutrient composition) and on the varying effects on different tasks related to cognitive functioning. For example, benefits of breakfast consumption were most evident on measures of memory and in terms of fewer errors on attention tasks especially later in the morning. A lot of research is currently being done in this area.

5.4 Conclusion

Despite the finding that breakfast consumption does not lead to a decreased energy intake over the day, this overview has shown clear benefits of having breakfast. The benefits of breakfast consumption are that it can prevent children and adolescents to become overweight or obese, and it has a positive effect on cognitive functioning in children and adolescents. In conclusion, because of the benefits of breakfast on weight and cognition, children and adolescents should be stimulated to have breakfast.

Acknowledgements

The valuable comments of René de Wijk, Ellen van Kleef, Milou Vrijhof, Ilse Polet, and Judith van der Horst are highly appreciated.

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