Changes in retail food environments around schools over 12 years and associations with overweight and obesity among children and adolescents in Flanders, Belgium

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Abstract

Background

Children have been found to be extra susceptible to the food environment. This research assessed changes in food environments near schools in Flanders between 2008 and 2020 and associations with children's and adolescents' weight status.

Methods

The food environment within a 500m and 1000m road network distance to all primary- and secondary schools was mapped using several spatial indicators. A generalized linear modelling approach was used to explore associations between these indicators and weight status of children and adolescents.

Results

Food environments near schools in Flanders were found to be unhealthy in 2020, with a significant increase in fast-food restaurants and convenience stores between 2008 and 2020. Food environments near schools with a higher proportion of children from a poor socio-economic background were found more unhealthy than those near schools with a lower proportion of such children, regardless of the urbanization level. A significant positive association was found between the density of fast food restaurants as well as convenience stores around primary schools and the weight status of children aged <6 years and 6-12 years. The association between the density of fast food restaurants and convenience stores around secondary schools and the weight status of adolescents, aged 13-14 and 15-18 years, was less clear.

Conclusion

Food environments around schools in Flanders became more unhealthy over time and were associated with children's weight status.

Background

Food environments have commonly been defined as 'the physical, economic, political and socio-cultural contexts in which people engage with the food system to make their decisions about acquiring, preparing and consuming food' (1, 2). The concept of the food environment demonstrates how the choices that people make regarding the foods they eat are to a significant degree influenced by the context within which they are made. Most current food environments do not encourage healthy eating (3). The ongoing obesity epidemic is at least partly a consequence of these unhealthy food environments (4). In its series on obesity, The Lancet states that 'Today's food environments exploit people's biological, physiological, social and economic vulnerabilities, making it easier for them to eat unhealthy foods' (5).

Adequate, healthy nutrition is especially important for young children and adolescents, as their bodies and brains are still developing. The link between unhealthy diets during childhood and physical- and mental health problems later in life has been clearly established (6, 7). The prevalence of childhood obesity has increased dramatically worldwide since the 1980s and is considered one of the most serious public health issues (8). In Flanders, in 2018 it was observed that almost one in five (16.2%) young people were overweight and 4.6% of young people suffered from obesity. One person in five (19.4%) in Flanders drank sugared soft drinks daily and 4.1% of people drank at least 1 liter of soft drinks daily in 2018 (9). Among 2-year-olds, 1 in 100 children in Flanders was obese in 2016, among 12 to 14-year-olds this was 4 in 100. At all ages, the proportion of overweight girls was higher than that of overweight boys. At all ages, children who are born or grow up in deprived areas had a less favorable weight status. Around 20% of 4-year-olds in deprived areas were overweight. Among non-privileged children, it was less than 1 in 10 at that age. From the age of 10 years onwards, at

least 32% of children in deprived areas were overweight. This was twice as much as for children who do not grow up in poverty(10).

Besides their homes, children spend most of their time in- and around their school. The healthiness of the food environment in- and outside the school perimeter is therefor particularly important. In their recent systematic review, (11) found consistent positive associations between obesogenic food environments near schools and the body weight of children aged 6–18 years. Most studies they reviewed found positive associations between food environment indicators such as the number of fast-food outlets or convenience stores near schools and weight status among children. They also found limited evidence for negative associations between healthy food environments around schools and weight status among children.

In their meta-analysis of 100 studies involving the food environment in and around schools, (12) found that interventions addressing food environments inside schools, such as increasing the vegetable and fruit offerings in school canteens and the banning of vending machines that sell sugar sweetened beverages have a positive effect on the children's weight, but the authors note that the effect of these measures are partly nullified when the food environment around schools is obesogenic. The food environment around schools can influence the children's meal choice in schools and therefor reduce the effectiveness of the measures addressing food environments in schools. Likewise, (13) note that the proximity of fast-food- and other unhealthy outlets near schools may lead to a greater exposure to unhealthy foods which can influence children's eating habits;.

The food environment inside schools can also influence the food environment around schools. (14) investigated the effect of the European school fruit scheme in schools which was implemented by various member states by the end of 2008. They found that supermarkets in a 500 meter radius around schools showed a significant decrease in the sales of junkfood (6.32%) compared with supermarkets outside this radius. The effect was only for regular supermarkets and not discount stores, leading the researchers to conclude that the campaign only had the intended effect in a subgroup of the population, namely the wealthier middle class who are less prone to overweight and obesity problems.

Studies have shown that children from families with low incomes generally consume less healthy diets and have higher BMI (Body Mass Index) scores (15, 16). Several studies emphasize the stronger impact of unhealthy food environments on the health of children from poor families. (11) found in their systematic review a positive correlation between children's weight status and the number of fast-food restaurants in their school environment, this correlation was stronger for children from underprivileged families. (17) found in their review that there was evidence for a strong correlation between the number of hot food takeaway restaurants and the socio-economic status of the area. Children who spend more time in these deprived areas were found to eat more fast-food and have a higher BMI.

When assessing the available evidence, it is clear that the food environment around schools has been much less studied than the food environment inside schools. Of the 100 studies that (12) reviewed, only six looked at how the external food environment influenced the children's weight. A possible reason for this is that changing the food environment around schools is more complex and requires greater political will. Before policy recommendations can be formulated, a better understanding and mapping of the food environment around schools and how it influences the children's health is needed.

In Flanders, food environments inside schools have previously been studied by the institute Gezond Leven (18). They found that education about healthy food is strongly embedded in all primary- and secondary schools and that most schools are implementing some health promoting measures such as reducing their offerings of sugar sweetened beverages. There is however still a lot of progress to be made: for example only 37% of secondary schools does not offer unhealthy snacks and only 36% of secondary schools is phasing out unhealthy beverages (19).

This study is the first one to map the food environment around primary and secondary schools in Flanders and evaluate trends over time and associations with children's weight status. The research objectives of this study were I) To determine the actual healthiness of the food environment in Flanders near schools (situation 2020, pre-covid19) II) To assess if and how the food environment near schools in Flanders changed between 2008 and 2020 and III) To determine if there are associations between the food environment in Flanders near schools, the socio-economic status of the schools' children and the children's weight status.

Methods

Study area

Belgium consists of three major regions: Flanders, Brussels and Wallonia. Flanders is an area in the northern part of Belgium. The region inhabits 6.629.143 people (57.5% of Belgian population), of which 1.123.000 are of school going age (2.5 to 17 years) (20). The region is strongly urbanized with a high population density (383.9 inhabitants/km²). This study comprised the entire territory of Flanders, including all schools and food stores and services in Flanders.

Data sources

Food outlets

The geographical coordinates of all food retailers (stores and services) in Flanders were obtained from the commercial Locatus database (www.locatus.com*)*. It covers the entire territory of Flanders and includes information such as the name and address of the retailer, the type of outlet and the size of the retail space.

Since 2008, Locatus systematically performs regular field audits in Belgium to map the locations, sizes and types of retailers for commercial purposes. The frequency of field audits varies from once a year - in shopping areas - to once every 2 or 3 years in locations outside shopping areas.

Locatus has its own field service, which visits, inventorizes and checks all points of sale in the Benelux on a yearly basis. For this study the databases from the years 2008, 2013 and 2020 were acquired. The original database included 33 types of retailers whose primary purpose is to sell food, which was too detailed for the purposes of this study. Therefore a reclassification into nine classes suitable for this study was done. The nine resulting classes of food retailers were supermarkets, confectionary stores, convenience stores, fastfood/takeaway/delivery outlets, shops that primarily sell animal products, full service restaurants, greengroces, bakeries and other shops. The complete reclassification can be consulted in Additional file 1.

Road network and urbanicity

The road network of Flanders was sourced from the 'Grootschalig Referentie Bestand Vlaanderen (GRB)', which is a freely available data source, managed by the Flemish government, that continually maps and updates spatial entities such as roads, buildings and waterways (21). The Degree of urbanization (DEGURBA) dataset, provided by Eurostat, was used to divide Flanders in regions that are 'essentially urban', 'intermediate' and 'essentially rural' (22).

Schools

The school data was acquired from the Department for Education Flanders and included the schools' unique ID, name, type and geographical coordinates. The schools were reclassified in primary schools (n = 3404, age 2.5–12 years) and secondary schools (n = 1195, age 13–18 years).

An anonymized dataset with aggregated socio-economic status (SES) indicators for the students of every school in Flanders was provided by the Flemish government. Previous research has demonstrated that these indicators are strong predictors for children's mental wellbeing, cognitive function and adiposity (23–25). The SES indicators available included the proportion of pupils/students for which the level of education of the mother was low and the proportion of pupils/students for which the home language was not Dutch.

The schools were divided in terciles for each SES indicator into 'high', 'medium', or 'low'. A high SES score means that the proportion of the schools' children with a low educated mother or for which the home language is not Dutch is high.

Weight status

A dataset of the weight status of all children for each school and for the years 2011–2016 was provided by the Flemish government agency 'Agentschap Zorg en Gezondheid'. The data consists of the mean BMI as well as the percentage of children that are overweight in each school. The data were stratified by sex and age group (< 6years, 6-12years, 13–14 years and 14–18 years) (See Additional file 2). Due to privacy reasons it was not possible to obtain the data on BMI and weight status from the individual children, only data at the school level were accessible for research. The height and weight of the children are measured when they visit the centers for pupils support (CLBs). These measures are obligatory as determined by a government decree, so parents or children cannot opt out unless they are sick on the day of the measurements. Height was measured barefoot, in light clothing (no jumper, shirt or jacket) with a SECA 213 mobile stadiometer. Weight was measured in underwear at a precision of at least 100 grams with a SECA877 or Seca Quadra 808 scale. The weight status is calculated by comparing the BMI of the children with the IOTF thresholds for overweight and obesity (26) and those of the WHO (for low BMI for age).

Selection indicators of the food environment

The first indicator that was calculated was the absolute density (number) of each food retail type within a 500- and 1000m road network distance from the main entrance of the school.

The 500- and 1000m road network distances were chosen based on common walking distances that most children can do fairly easily. At an average walking speed of 5km/h, a person would need approximately 6 or 12 minutes to walk 500- or 1000m respectively. Other studies in the same context, such as (27), assumed the same common walking distances. The second indicator that was computed was the percentage of schools that had at least one food retailer of a certain type within a walking distance of 500- or 1000 meter from the entrance of the school. The final indicator that was determined was the shortest distance from each school entrance to the nearest fast food outlet, supermarket and convenience- or confectionary store. These types of retailers were identified to be the most probable types of food shops that children would visit during lunchbreak or outside of school hours.

Geographical analyses

The analyses were performed in QGIS 3.16.5 and PostGIS 3.1. The service area algorithm in QGIS created a road distance network of 500- and 1000m around the entrance of every primary- and secondary school. The absolute density of each retail type and the percentage of schools that had at least one food retailer of a certain type in their food environment were calculated based on these road distance networks. The Dijkstra algorithm, implemented in the pgRouting package (PostGIS) was used to calculate the shortest network distances needed for the third indicator. A custom SQL query was written to automate the process and perform the analyses for all schools simultaneously.

Statistical analyses

The statistical analyses were performed with SAS9.4. Associations between the density of fast food, takeaway, delivery outlets and convenience stores around schools, and mean BMI and % of overweight children was determined through

generalized linear models adjusted for the level of urbanization (DEGURBA), socio-economic status of children at school level (proportion of children for which education level of the mother is low) and sex. Analyses were stratified by age group (< 6 years, 6–12 years, 13–14 years and 15–18 years) and by buffer (500m/1000m from the school).

A lag time of zero, one and two years was considered for assessing the association between exposure to food environments and weight status. Children's BMI data from the school years 2010-11, 2013-14, 2014-15 and 2015-16 were used and linked with Locatus data from the years 2008 and 2013. In view of the many analyses conducted, a Bonferroni correction was applied, where a p-value of < 0.0006 (0.05/88) was considered statistically significant.

Results

Trends in food environments around schools in Flanders

The mean absolute density of different food retail types within a 500m- and 1000m walking distance buffer from the school entrance can be found in Table 1 (primary schools) and Table 2 (secondary schools). The absolute density of more traditional stores around schools such as bakeries, local shops selling animal products and greengrocers significantly declined between 2008 and 2020. In the case of greengrocers, their numbers approximately halved from 0.29 stores to 0.14 stores on average within a 500m walking distance buffer from primary schools (Table 1, Table 2).

Table 1
Mean absolute density (i.e. number of outlets) of different types of food outlets within 500m and 1000m road network distance from the main entrance of primary schools (N=3404) in Flanders (year=2008 & 2020) – Significant results comparing 2008 & 2020 indicated in bold.

buffer	***food outlet type***	***2008***				***2020***			
		mean	*Lower 95%CI*	*Upper 95%CI*	*max*	*mean*	*Lower 95%CI*	*Upper 95%CI*	*max*
500m	*Shops selling animal products*	1.22	1.16	1.28	18	0.84	0.79	0.89	20
500m	*Bakeries*	1.50	1.44	1.56	15	1.17	1.12	1.22	20
500m	*Confectionary Stores*	*0.43*	*0.38*	*0.48*	*44*	*0.47*	*0.41*	*0.53*	*61*
500m	*Convenience Stores*	1.02	0.93	1.11	44	1.25	1.13	1.37	65
500m	*Fast food/takeaway/delivery outlets*	1.86	1.77	1.95	34	2.19	2.06	2.31	42
500m	*Full Service Restaurants*	*3.54*	*3.22*	*3.87*	*166*	*4.24*	*3.87*	*4.62*	*191*
500m	*Greengrocers*	0.29	0.27	0.31	4	0.14	0.12	0.15	4
500m	*Other Shops*	0.14	0.13	0.16	3	0.07	0.06	0.08	2
500m	*Supermarkets*	*0.60*	*0.58*	*0.63*	*7*	*0.65*	*0.61*	*0.68*	*10*
1000m	*Shops selling animal products*	3.25	3.10	3.40	40	2.29	2.17	2.40	35
1000m	*Bakeries*	3.76	3.61	3.91	34	2.93	2.80	3.06	38
1000m	*Confectionary Stores*	*1.28*	*1.16*	*1.40*	*52*	*1.46*	*1.31*	*1.62*	*70*
1000m	*Convenience Stores*	*3.19*	*2.90*	*3.48*	*106*	*3.83*	*3.47*	*4.19*	*143*
1000m	*Fast food/takeaway/delivery outlets*	5.28	5.01	5.56	91	6.34	5.96	6.73	111
1000m	*Full Service Restaurants*	*11.63*	*10.60*	*12.67*	*387*	*13.80*	*12.58*	*15.03*	*420*
1000m	*Greengrocers*	0.80	0.75	0.84	9	0.41	0.38	0.44	10
1000m	*Other Shops*	0.42	0.39	0.45	9	0.22	0.20	0.23	6
1000m	*Supermarkets*	1.73	1.66	1.80	16	2.09	1.98	2.19	28

Table 2
Mean absolute density (i.e. number of outlets) of different types of food outlets within 500m and 1000m road network distance from the main entrance of secondary schools (N = 1195) in Flanders (year = 2008 & 2020) – Significant results comparing 2008 & 2020 indicated in bold.

buffer	***food outlet type***	***2008***				***2020***			
		mean	*Lower 95%CI*	*Upper 95%CI*	*max*	*mean*	*Lower 95%CI*	*Upper 95%CI*	*max*
500m	*Shops selling animal products*	1.68	1.56	1.81	17	1.18	1.08	1.27	14
500m	*Bakeries*	1.92	1.80	2.04	13	1.48	1.38	1.59	11
500m	*Confectionary Stores*	*0.99*	*0.85*	*1.14*	*44*	*1.07*	*0.90*	*1.25*	*61*
500m	*Convenience Stores*	1.62	1.44	1.80	45	2.03	1.82	2.25	55
500m	*Fast food/ takeaway/delivery outlets*	3.05	2.83	3.27	39	3.68	3.40	3.97	41
500m	*Full Service Restaurants*	*8.03*	*7.17*	*8.89*	*152*	*9.67*	*8.68*	*10.66*	*172*
500m	*Greengrocers*	0.41	0.37	0.45	4	0.23	0.20	0.26	4
500m	*Other Shops*	0.29	0.26	0.32	4	0.13	0.11	0.15	2
500m	*Supermarkets*	0.76	0.71	0.82	6	0.97	0.89	1.04	9
1000m	*Shops selling animal products*	5.69	5.36	6.01	39	4.04	3.78	4.29	33
1000m	*Bakeries*	6.37	6.04	6.70	36	4.90	4.62	5.17	37
1000m	*Confectionary Stores*	*3.23*	*2.89*	*3.57*	*53*	*3.77*	*3.31*	*4.24*	*70*
1000m	*Convenience Stores*	6.15	5.52	6.79	99	7.61	6.81	8.42	138
1000m	*Fast food/takeaway/delivery outlets*	10.21	9.56	10.86	88	12.68	11.76	13.60	113
1000m	*Full Service Restaurants*	*28.69*	*25.83*	*31.56*	*363*	*34.12*	*30.80*	*37.44*	*409*
1000m	*Greengrocers*	1.37	1.27	1.46	9	0.70	0.63	0.77	10
1000m	*Other Shops*	0.96	0.89	1.04	9	0.45	0.41	0.49	5
1000m	*Supermarkets*	2.69	2.55	2.83	16	3.61	3.39	3.83	30

On the other hand, food retail types such as fast food, takeaway and delivery outlets, convenience stores and supermarkets saw significant increases between 2008 and 2020. For example the mean density of fast food-, takeaway and delivery outlets within a 500m walking distance from the school entrance of primary schools increased significantly from 1.86 stores to 2.19 stores between 2008 and 2020. Full service restaurants were most ubiquitous around primary- and secondary schools, although their increase between 2008 and 2020 was not significant.

They were followed by fast food, take-away and delivery outlets, bakeries and local stores selling animal products (Table 1, Table 2). When comparing the densities of retail types around primary- and secondary schools (Table 2) higher densities were observed for the latter.

Similar results were found for the indicator on the percentage of schools with at least one outlet of a certain retail type within a walking distance of 500- or 1000m from the entrance of the school (Table 3). A significant decrease is seen for the percentage of schools with at least one traditional food outlet (bakeries, shops selling animal products and greengrocers) while the percentage of schools with at least one other food outlet such as full service restaurants and convenience stores increased between 2008 and 2020. The percentage of primary- and secondary schools with at least one fast food, delivery or takeaway outlet within a walking distance of 1000m was 82.9% and 90.9% in 2020 respectively (Table 3).

Table 3
Percentage of primary/secondary schools with at least one food outlet from the different retail types within 500m and 1000m road network distance from the main entrance of the schools (year=2008 & 2020)

Food outlet type	***School type***	***500m buffer***		***1000m buffer***	
		2008	*2020*	*2008*	*2020*
Full Service Restaurants	*primary*	*58.3*	*62.7*	*80.1*	*83.3*
	secondary	*70.5*	*73.7*	*91.1*	*92.6*
Fast Food/Takeaway/Delivery	*primary*	*61.5*	*64.0*	*81.1*	*82.9*
	secondary	*69.0*	*70.8*	*89.7*	*90.9*
Confectionary Stores	*primary*	*20.3*	*21.7*	*40.0*	*40.8*
	secondary	*36.4*	*36.5*	*66.6*	*66.6*
Bakeries	*primary*	*66.0*	*60.6*	*83.6*	*79.4*
	secondary	*66.1*	*61.3*	*88.5*	*86.0*
Supermarkets	*primary*	*43.0*	*40.9*	*70.0*	*68.0*
	secondary	*50.5*	*53.0*	*82.3*	*85.3*
Shops selling animal products	*primary*	*56.5*	*45.8*	*76.6*	*69.0*
	secondary	*61.3*	*52.6*	*84.9*	*81.7*
Convenience Stores	*primary*	*40.3*	*43.6*	*59.1*	*62.0*
	secondary	*49.9*	*56.3*	*75.6*	*80.3*
Greengrocers	*primary*	*22.8*	*11.6*	*43.6*	*25.9*
	secondary	*30.9*	*18.0*	*61.3*	*40.1*
Other Shops	*primary*	*11.9*	*7.1*	*26.6*	*17.8*
	secondary	*22.1*	*12.0*	*51.5*	*33.6*

When looking at the shortest median distance from a school entrance to the nearest retail outlet of a certain type, the differences between 2008 and 2020 were not significant. This means that the median distance that children needed to walk to reach one of these outlets has not changed since 2008. Shortest median distances were between 300 and 500 meters for most outlet types, meaning that children on average needed to walk between 4–6 minutes from the school

entrance to reach the nearest outlet. For instance, the median walking distance from primary- and secondary schools to the nearest fast-food outlet was in 2020 369.2m (IQR 202m-728.4m) and 325.3m (IQR 172.7m-574.7m) respectively, while the median distance to the nearest convenience- or confectionary store was 525.9m (IQR 263.1m- 1464.0m) and 379.8m (IQR 208.5m-749.3m) respectively. The median distance to the nearest supermarket was 640.3m (IQR 353.7m-1432.4m) for primary schools and 501.3m (IQR 321.3m-747.1m) for secondary schools. The distances were lower for secondary- compared to primary schools, meaning that older children have easier access to unhealthy foods. The table with the full results and interquartile ranges can be found in Additional file 3.

Associations between food environment indicators, socio-economic status and the level of urbanization

Schools that have a high % of pupils who have a low educated mother or whose home language is not Dutch, have unhealthier food environments with a higher density of fast-food, takeaway and delivery outlets and convenience stores compared to schools with a medium or low % of pupils from lower socioeconomic backgrounds (Fig. 1). This gradient was most pronounced for primary schools. For example, a primary school in Flanders that has a high % of pupils with a lower educated mother had on average 12.1 +- 1 fast-food, takeaway or delivery outlets and 8.8 +- 1 convenience stores within a 1000 meter walking distance, while a primary school that scores low on this indicator had on average only 3.6 +- 0.4 fast-food, takeaway or delivery outlets and 2.6+-0.24 convenience stores nearby. This gradient remained when the results are corrected for the level of urbanization, although the density of stores was lower outside urban centers (Additional file 4). The results for the % of pupils whose home language is not Dutch were similar and can be found in additional file 4.

The following map shows the geographical relationship between the density of fast food, takeaway and delivery outlets and convenience stores within a 1000m walking distance from primary schools and the % of pupils that have a lower educated mother (Fig. 2). The schools with a high density of fast-food, takeaway and delivery outlets and convenience stores are predominantly located in urban city centers such as Antwerp, Gent and Leuven. Besides a few exceptions in Gent, all these schools are colored orange or red meaning that they have an intermediate or high % of children with a lower educated mother.

Associations Between Food Environments Near Schools And Children’s Weight Status

The BMI and overweight data (Additional file 2) of the school years 2010–2011 until 2015–2016 were averaged for each school and stratified in the age groups younger than 6 years, 6–12 years, 13–14 years and 15–18 years by Vlaams Agentschap Zorg and Gezondheid. These data are used as the dependent variable in the generalized linear models. The results of the models that link the density of fast-food, takeaway and delivery outlets with the children’s weight status can be seen in Table 4.

Table 4
Associations between the density of fast-food/takeaway/delivery outlets around schools and the schools' children's weight status, by age group and buffer (500m/1000m), adjusted for sex, level of urbanicity of municipality and % of pupils with lower educated mother.

school year	Locatus year	outlet	buffer	indicator weight status	Age group	Crude		Adjusted	
						Coefficient/SE	p	Coefficient/SE	p
2010-11	2008	fast food	500m	Mean BMI	Younger than 6 years	0.022 / 0.002	< 0.001	0.006 / 0.002	0.002
2010-11	2008	fast food	500m	Mean BMI	6–12 years	0.077 / 0.004	< 0.001	0.057 / 0.004	< 0.001
2010-11	2008	fast food	500m	Mean BMI	13–14 years	0.012 / 0.006	0.014	0.002 / 0.005	0.641
2010-11	2008	fast food	500m	Mean BMI	15–18 years	0.001 / 0.009	0.940	0002 / 0.009	0.835
2010-11	2008	fast food	1000m	Mean BMI	Younger than 6 years	0.010 / 0.000	< 0.001	0.004 / 0.000	< 0.001
2010-11	2008	fast food	1000m	Mean BMI	6–12 years	0.035 / 0.001	< 0.001	0.028 / 0.002	< 0.001
2010-11	2008	fast food	1000m	Mean BMI	13–14 years	0.014 / 0.002	< 0.001	0.005 / 0.002	0.009
2010-11	2008	fast food	1000m	Mean BMI	15–18 years	0.002 / 0.003	0.553	0.000 / 0.003	0.821
2010-11	2008	fast food	500m	% overweight	Younger than 6 years	0.282 /0.032	< 0.001	0.118 / 0.032	0.001
2010-11	2008	fast food	500m	% overweight	6–12 years	0.190 / 0.028	< 0.001	0.084 /0.028	0.003
2010-11	2008	fast food	500m	% overweight	13–14 years	-0.026 / 0.044	0.804	-0.023 / 0.043	0.598
2010-11	2008	fast food	500m	% overweight	15–18 years	0.049 / 0.067	0.466	0.102 / 0.070	0.148
2010-11	2008	fast food	1000m	% overweight	Younger than 6 years	0.107 / 0.010	< 0.001	0.044 / 0.011	< 0.001
2010-11	2008	fast food	1000m	% overweight	6–12 years	0.099 / 0.009	< 0.001	0.048 /0.010	< 0.001
2010-11	2008	fast food	1000m	% overweight	13–14 years	0.028 / 0.015	0.061	0.004 /0.016	0.814
2010-11	2008	fast food	1000m	% overweight	15–18 years	0.030 / 0.023	0.190	0.044 / 0.025	0.087
2015-16	2013	fast food	500m	Mean BMI	Younger than 6 years	0.021 / 0.002	< 0.001	0.006 / 0.002	0.001

school year	Locatus year	outlet	buffer	indicator weight status	Age group	Crude		Adjusted	
2015-16	2013	fast food	500m	Mean BMI	6–12 years	0.089 /0.005	< 0.001	0.059 / 0.005	< 0.001
2015-16	2013	fast food	500m	Mean BMI	13–14 years	-0.002 / 0.007	0.778	-0.000 / 0.005	0.876
2015-16	2013	fast food	500m	Mean BMI	15–18 years	-0.021 / 0.009	0.023	-0.016 / 0.008	0.053
2015-16	2013	fast food	1000m	Mean BMI	Younger than 6 years	0.009 / 0.000	< 0.001	0.003 / 0.000	< 0.001
2015-16	2013	fast food	1000m	Mean BMI	6–12 years	0.040 / 0.001	< 0.001	0.028 / 0.002	< 0.001
2015-16	2013	fast food	1000m	Mean BMI	13–14 years	0.006 / 0.002	0.005	0.000 / 0.002	0.888
2015-16	2013	fast food	1000m	Mean BMI	15–18 years	-0.004 / 0.003	0.146	-0.007 / 0.003	0.011
2015-16	2013	fast food	500m	% overweight	Younger than 6 years	0.246 / 0.029	< 0.001	0.076 / 0.028	< 0.001
2015-16	2013	fast food	500m	% overweight	6–12 years	0.268 / 0.026	< 0.001	0.097 / 0.025	< 0.001
2015-16	2013	fast food	500m	% overweight	13–14 years	0.035 /0.046	0.451	0.029/ 0.044	0.504
2015-16	2013	fast food	500m	% overweight	15–18 years	-0.011 / 0.068	0.872	-0.045 / 0.069	0.512
2015-16	2013	fast food	1000m	% overweight	Younger than 6 years	0.111 / 0.009	< 0.001	0.046 / 0.010	< 0.001
2015-16	2013	fast food	1000m	% overweight	6–12 years	0.117 / 0.008	< 0.001	0.043 / 0.008	< 0.001
2015-16	2013	fast food	1000m	% overweight	13–14 years	0.045 / 0.015	0.002	0.010 / 0.015	0.521
2015-16	2013	fast food	1000m	% overweight	15–18 years	0.009 / 0.021	0.681	-0.013 / 0.022	0.574
2013-14	2013	fast food	500m	Mean BMI	Younger than 6 years	0.020 / 0.002	< 0.001	0.005 / 0.002	0.003
2013-14	2013	fast food	500m	Mean BMI	6–12 years	0.093 /0.005	< 0.001	0.068 / 0.005	< 0.001
2013-14	2013	fast food	500m	Mean BMI	13–14 years	-0.008 / 0.006	0.190	-0.002 / 0.005	0.638
2013-14	2013	fast food	500m	Mean BMI	15–18 years	-0.010 / 0.009	0.294	-0.001 / 0.009	0.885

school year	Locatus year	outlet	buffer	indicator weight status	Age group	Crude		Adjusted	
2013-14	2013	fast food	1000m	Mean BMI	Younger than 6 years	0.009 / 0.000	< 0.001	0.003 / 0.000	< 0.001
2013-14	2013	fast food	1000m	Mean BMI	6–12 years	0.042 / 0.001	< 0.001	0.031 / 0.002	< 0.001
2013-14	2013	fast food	1000m	Mean BMI	13–14 years	0.003 / 0.002	0.126	-0.001 /0.001	0.469
2013-14	2013	fast food	1000m	Mean BMI	15–18 years	-0.000 / 0.003	0.871	0.000 / 0.003	0.730
2013-14	2013	fast food	500m	% overweight	Younger than 6 years	0.261 / 0.29	< 0.001	0.068 / 0.029	0.018
2013-14	2013	fast food	500m	% overweight	6–12 years	0.249 / 0.026	< 0.001	0.118 / 0.024	< 0.001
2013-14	2013	fast food	500m	% overweight	13–14 years	0.041 / 0.045	0.371	0.089 / 0.044	0.045
2013-14	2013	fast food	500m	% overweight	15–18 years	0.018 / 0.066	0.786	0.065 / 0.067	0.331
2013-14	2013	fast food	1000m	% overweight	Younger than 6 years	0.107 / 0.009	< 0.001	0.031 / 0.010	0.002
2013-14	2013	fast food	1000m	% overweight	6–12 years	0.102 / 0.008	< 0.001	0.035 / 0.008	< 0.001
2013-14	2013	fast food	1000m	% overweight	13–14 years	0.036 / 0.014	0.013	0.026 / 0.015	0.089
2013-14	2013	fast food	1000m	% overweight	15–18 years	0.016 / 0.020	0.421	0.022 / 0.022	0.308
2014-15	2013	fast food	500m	Mean BMI	Younger than 6 years	0.026 / 0.002	< 0.001	0.010 / 0.002	< 0.001
2014-15	2013	fast food	500m	Mean BMI	6–12 years	0.095 / 0.004	< 0.001	0.068 / 0.005	< 0.001
2014-15	2013	fast food	500m	Mean BMI	13–14 years	-0.013 / 0.006	0.039	0.000 / 0.006	0.946
2014-15	2013	fast food	500m	Mean BMI	15–18 years	-0.014/ 0.009	0.107	-0.017 / 0.009	0.079
2014-15	2013	fast food	1000m	Mean BMI	Younger than 6 years	0.011 / 0.000	< 0.001	0.005 / 0.000	< 0.001
2014-15	2013	fast food	1000m	Mean BMI	6–12 years	0.043 / 0.001	< 0.001	0.031 / 0.002	< 0.001
2014-15	2013	fast food	1000m	Mean BMI	13–14 years	0.002 / 0.002	0.354	-0.002 / 0.002	0.322

school year	Locatus year	outlet	buffer	indicator weight status	Age group	Crude		Adjusted	
2014-15	2013	fast food	1000m	Mean BMI	15–18 years	0.002 / 0.002	0.437	-0.003 / 0.003	0.300
2014-15	2013	fast food	500m	% overweight	Younger than 6 years	0.273 / 0.028	< 0.001	0.100 / 0.033	0.003
2014-15	2013	fast food	500m	% overweight	6–12 years	0.197 / 0.023	< 0.001	0.080 / 0.026	0.002
2014-15	2013	fast food	500m	% overweight	13–14 years	-0.014 / 0.044	0.749	0.050 / 0.048	0.305
2014-15	2013	fast food	500m	% overweight	15–18 years	-0.121 / 0.064	0.059	-0.111 / 0.075	0.138
2014-15	2013	fast food	1000m	% overweight	Younger than 6 years	0.114 / 0.009	< 0.001	0.053 / 0.010	< 0.001
2014-15	2013	fast food	1000m	% overweight	6–12 years	0.101 / 0.008	< 0.001	0.046 / 0.008	< 0.001
2014-15	2013	fast food	1000m	% overweight	13–14 years	0.025 / 0.014	0.082	0.030 / 0.016	0.054
2014-15	2013	fast food	1000m	% overweight	15–18 years	0.006 / 0.021	0.779	-0.006 / 0.024	0.806

All models showed a positive association between the density of fast-food outlets and convenience stores and mean BMI and % overweight for children < 6 years and 6–12 years (for the majority of models the association is significant after applying the Bonferroni correction $p < 0.0006$). This was the case for both buffers (500m/1000m) and the three lag periods (zero, one or two years). For example, for every additional fast-food, takeaway and delivery outlet within a 500m walking distance from the school entrance, the mean BMI of children 6–12 increased by 0.057 +- 0.004 kg/m² in 2010–2011, and 0.059 +- 0.005 kg/m² in 2015/16 considering a 2 year lag time. When looking at the association between the density of convenience stores and the mean BMI of children 6–12 (See Additional file 5), each additional convenience store in a 500m perimeter around primary schools is found to increase the children's BMI with 0.018 +- 0.004 kg/m² in 2010–2011 and 0.024 +- 0.004 kg/m² in 2015–2016, considering a 2 year lag time.

For 13–14 year old children, when corrected for multiple testing, there were no significant associations between exposure to fast food outlets and weight status, and there was only a significant association between exposure to convenience stores and % of children that is overweight and mean BMI for the one-year lag time. For 15–18 year olds, when corrected for multiple testing, there were no associations between exposure to fast food outlets or convenience stores and mean BMI or the % of children that is overweight, regardless of the lag time taken into account. The results for convenience stores were similar and can be found in Additional file 5.

Discussion

This study showed that food environments around schools in Flanders were generally unhealthy with children having increasingly easier access to unhealthy food retailers such as convenience stores and fast-food, takeaway and delivery outlets. In addition, traditional stores such as bakeries, greengrocers and stores that sell animal products around schools

declined over a 12 year period. They were replaced by full service restaurants, convenience stores, fast-food, takeaway and delivery outlets and confectionary stores which significantly increased over the same time period. These changes probably reflect a broader change in the food landscape in Flanders and are similar to results found in the Netherlands (28). The differences in indicator values between primary- and secondary schools are likely because primary schools are often located in semi-urban areas while most secondary schools are built in more dense, urban areas. Hence the density of food retailers around secondary schools is higher and walking distances are shorter than the food environments around primary schools.

Food environments near schools with a higher proportion of pupils from lower socio-economic backgrounds were found to be more unhealthy. This gradient was most pronounced for primary schools and remains after correcting for the level of urbanization. Students from these schools often come from impoverished families that lack knowledge about a healthy nutritious diet and therefor are extra vulnerable to succumb to the allure of unhealthy food environments (11, 17). The reason that food environments near these schools were more unhealthy is likely due to supply and demand effects. Because children from impoverished families often eat more unhealthy at home, they are also more likely to eat less healthy outside their home environment (29).

Food retailers that offer unhealthy food will be drawn more to the schools where these children go to (11), giving them plenty of opportunity to continue the diet they are used to at home, thus creating a vicious cycle.

A significant positive association was found between the food environment near schools and the mean BMI and % of children that is overweight for children < 6 years and 6–12 years but not for children 13–14 years and 15–18 years. Children < 6 years and 6–12 years generally commute to their school under parental supervision and cannot leave the school during lunch break. On a first glance they interact less with the food environment near their school than older children who often can leave the school perimeter during lunch break and are more independent and free to determine their own food choices. Research however has shown that solely being exposed to an unhealthy food environment can lead to a more unhealthy diet (30, 31). Young children are very susceptible to marketing and merely passing through an unhealthy food environment twice a day can lead them to craving more sugary snacks and/or fatty foods, influencing their parents' purchasing behavior. Older children (13–14 years and 15–18 years) on the other hand, are much more mobile and are not necessarily restricted to the food environment near their school, but interact with many more different food environments. Around this age, they often experience a growth spurt meaning that an unhealthy diet won't necessarily show in their weight status right away but might create dietary habits that can lead to excess weight later in life. Previous research has shown that a high BMI and an increased prevalence of cardio metabolic risk factors such as high levels of LDL cholesterol or elevated blood pressure are not always correlated (32).

Possible measures to improve the food environment around schools that local municipalities can take are to limit the number of unhealthy outlets or forbid the establishment of new unhealthy outlets near a school. It is crucial that the Flemish government revises local planning- and zoning policies to give local policymakers the appropriate legal instruments.

Examples from other countries are ubiquitous: For example since the early 2010's, several districts in London have established exclusion zones around target locations such as local centers, parks and schools, banning hot food takeaways in these zones completely (33). In total 165 (50.5%) of local government areas in England have a specific policy targeting fast-food outlets, of which 56 (34.1%) are health focused (34). In Korea, Green Food Zones were created in 2009 within a 200m perimeter around schools to construct a safe and sanitary food environment (35). The Green Food Zones are managed by supervisors and the sale of low quality food for children was banned. In 2008, Los Angeles implemented a one year moratorium on opening or expanding fast-food outlets in the South region (36).

Local authorities can also oblige unhealthy outlets to offer a minimum amount of healthy options at a lower price than the unhealthy ones. Another option is to limit opening hours of unhealthy food outlets before- and after school hours. Governmental programs to change the food environment inside schools are likely to also have an effect on the outside school environment (14). Any governmental attempt to change the external food environment is likely to meet with some resistance, both from shop owners and the general public. It is therefore important that government, when implementing these measures, informs the public behind the reason of the measure.

This research provides policy makers in Flanders with important data about the food environment near schools, which can be used as a foundation to create policies aimed at improving the food environment. Recommendations for further research include measuring and modelling additional health indicators such as the children's cholesterol level, triglycerides, blood pressure, etc.. Another suggestion for future studies is to explore the link between the food environment outside schools and the food environment inside schools and the combined impact they have on the children's weight status.

This study has some key strengths and limitations. This is the first comprehensive survey on retail food environments around schools in Flanders, using the largest assembled food outlet list. The locatus data has previously been found accurate in a Dutch validation study (37). In addition, measured weight and height data from a large sample of children and adolescents in Flanders was used. It is important to note that these data were anonymized, aggregated an stratified by sex and age group on the school level by the Flemish government agency 'Agentschap Zorg en Gezondheid'. Due to privacy reasons, data on BMI and weight status of individual children were not available for research. Hence, the nature of the data did not allow for within-school cluster analysis using the individual's children BMI, neither did it allow for longitudinal statistical analysis that would account for repeated measurements of adiposity on the same children. Although 500- and 1000 m are common walking distances, the definition of neighborhoods in spatial studies, such as in this study, is quite arbitrary. The study setup did not allow to map individual children's journeys from home to school and back through the food environment, neither did it account for other individual changes in risk factors for obesity such as exercise, sleep and stress.

Conclusion

The food environment near schools in Flanders was characterized comprehensively for the first time using three spatial indicators and was found to have become more unhealthy between 2008 and 2020, with children having easy access to unhealthy food outlets such as fast-food restaurants and convenience stores. This result is exacerbated for schools with a high % of children that have a lower educated mother or whose home language is not Dutch, making these children extra susceptible for the detrimental health consequences of an unhealthy food environment. Our findings show that there is a significant positive association between the BMI and the % of children that are overweight and the school food environment for children < 6 years and 6–12 years. For children age 13–14 years and 15–18 years no significant associations are found. Policymakers are advised to use these results to formulate policies to improve the food environment near schools and protect children's health.

Abbreviations

BMI
Body Mass Index
SES
Socio-Economic Status indicators

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Human Ethics Committee of the University of Ghent. Measures on weight and height among children are obligatory as determined by a Flemish government decree (legislation), so parents or children cannot opt out unless they are sick on the day of the measurements. Informed consent was therefore waived by the Human Ethics Committee of the University of Ghent.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

Dr. Smets has nothing to declare.

Dr. Vandevijvere has nothing to declare.

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Authors' contributions

VS calculated the geographical indicators of the food environment. SV did the statistical analysis linking the food environment with the SES and BMI data. Both authors participated in writing the final publication. All authors read and approved the final manuscript.

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Figures

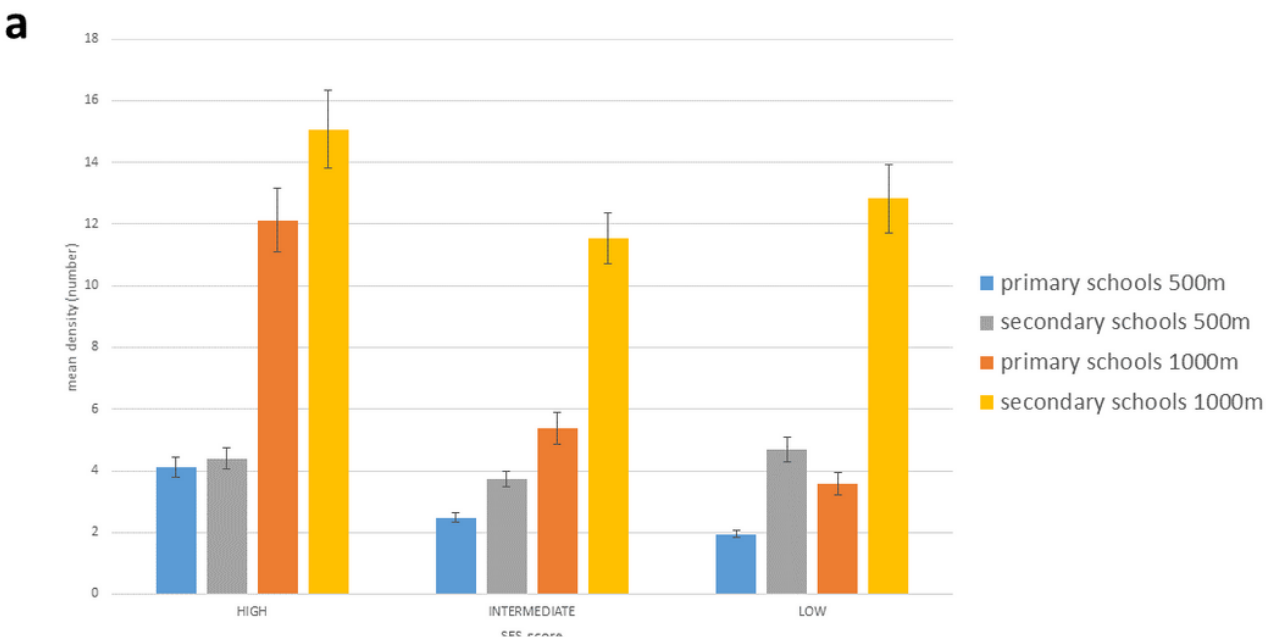

Figure 1

The mean absolute density (95% CI) of a) fastfood/takeaway and delivery oulets and b) convenience stores within a 500m and 1000m walking distance from the school entrance of primary schools and secondary schools (year 2020) according to a high, intermediate or low percentage of students with a lower educated mother.

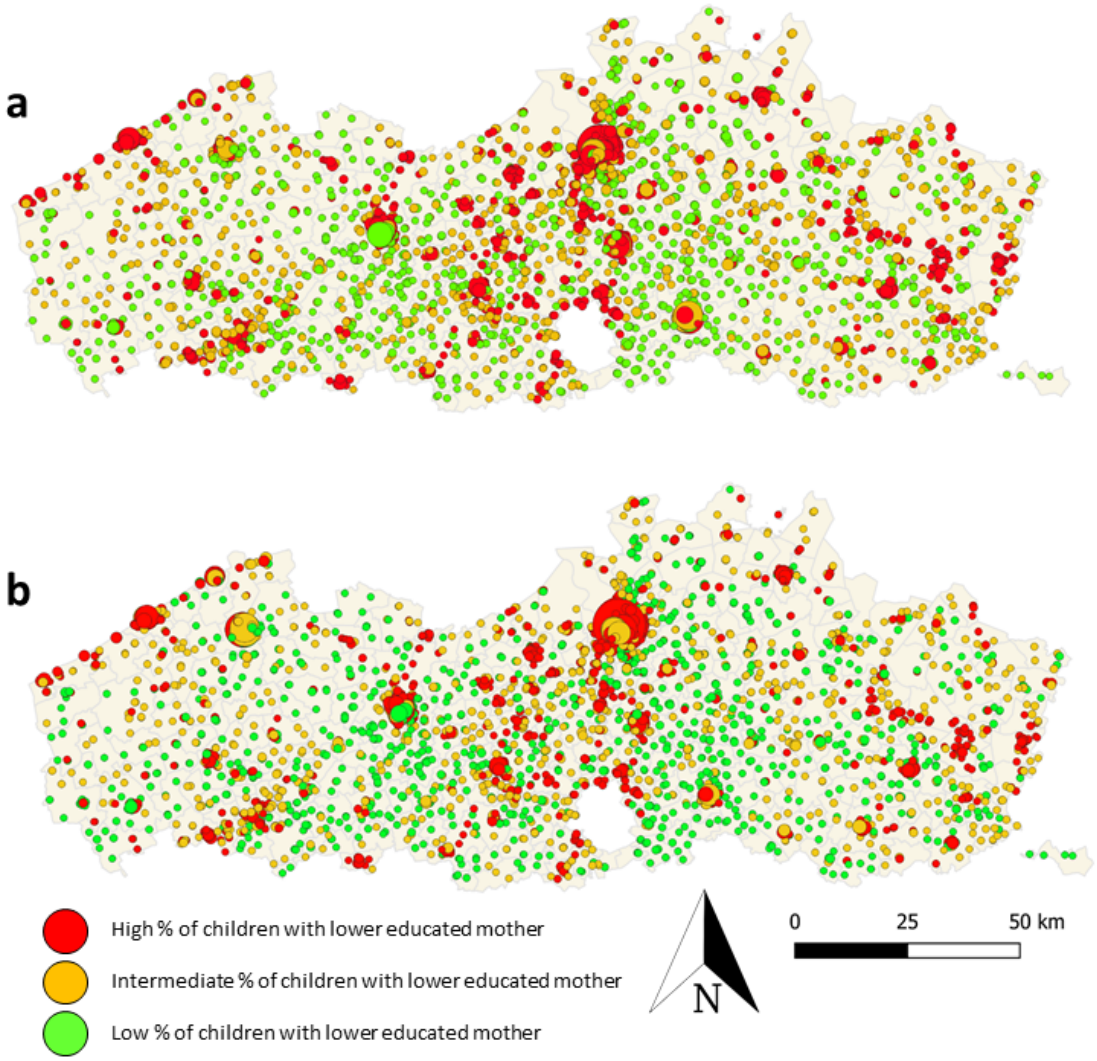

Figure 2

Location of primary schools in Flanders. The size of the circle varies depending on a) the density of fast-food/takeaway and delivery outlets and b) convenience stores within a 1000m walking distance from the school entrance. The color of the circle shows if the school as a high, intermediate or low percentage of students with a lower educated mother (year 2020).

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