Public Health Nutrition: 17(3), 614–624 doi:10.1017/S1368980013000323

Identification of lifestyle patterns associated with obesity and fat mass in children: the Healthy Growth Study

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Submitted 17 July 2012: Final revision received 5 December 2012: Accepted 22 January 2013: First published online 26 March 2013

Abstract

Objective: To investigate possible associations of lifestyle patterns with obesity and fat mass in children.
Design: Cross-sectional epidemiological study. Principal component analysis was used to identify lifestyle patterns.
Setting: Primary schools from four regions in Greece.
Subjects: A total of 2073 schoolchildren (aged 9–13 years).
Results: Children in the fourth quartile of the lifestyle pattern combining higher dairy foods with more adequate breakfast consumption were 39·4 %, 45·2 % and 32·2 % less likely to be overweight/obese and in the highest quartile of sum of skinfold thicknesses and fat mass, respectively, than children in the first quartile of this pattern. Similarly, children in the fourth quartile of a lifestyle pattern comprising consumption of high-fibre foods, such as fruits, vegetables and wholegrain products, were 27·4 % less likely to be in the highest quartile of sum of skinfold thicknesses than children in the first lifestyle pattern quartile. Finally, children in the fourth quartile of a lifestyle pattern characterized by more time spent on moderate-to-vigorous physical activity and more frequent meals were 38·0 %, 26·3 % and 29·5 % less likely to be overweight, centrally obese and in the highest quartile of fat mass, respectively, than their peers in the first quartile of this lifestyle pattern (all $P < 0·05$).
Conclusions: The current study identified three lifestyle patterns (i.e. one pattern comprising higher dairy consumption with a more adequate breakfast; a second pattern characterized by increased consumption of high-fibre foods; and a third pattern combining higher physical activity levels with more frequent meals), which were all related with lower odds of obesity and/or increased fat mass levels. From a public health perspective, promotion of these patterns among children and their families should be considered as one of the components of any childhood obesity preventive initiative.

Keywords
Children
Adiposity indices
Lifestyle patterns
Diet
Physical activity

In developed countries the prevalence of childhood obesity has reached epidemic proportions[1]. Childhood obesity has been associated with hypertension, dyslipidaemia and insulin resistance[2]. Most importantly, childhood obesity often tracks into adulthood[2,3], where it becomes associated with an increased risk of mortality from chronic non-communicable diseases[4]. In recent years marked lifestyle changes have occurred resulting in increased sedentary behaviours, decreased time spent in physical activities and increased consumption of energy-dense foods[1].

Although childhood obesity has strongly been associated with several energy balance-related behaviours, the actual aetiology of increased adiposity in children requires further investigation due to its complex and multifactorial nature. In this context, it is very important to examine the possible synergistic role of several lifestyle factors on adiposity in children[5]. A common approach to examine the possible synergy of such factors is the development of specific dietary and lifestyle patterns. Principal component analysis (PCA) is frequently used for this purpose, since it enables the grouping of several strongly associated behaviours into patterns.

Recent epidemiological studies have highlighted certain lifestyle patterns that when combined can significantly

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increase the risk of childhood obesity[6,7]. More specifically, certain eating behaviours such as infrequent meals, breakfast skipping, lower adherence to the Mediterranean diet and higher consumption of sugar-sweetened beverages, fruit juice, salty snacks and French fries, as well as lower consumption of dairy products, fruits and vegetables, have consistently been reported as the most important factors positively associated with childhood obesity[8]. Additionally, increased time spent in front of screens (i.e. television, games console and computer), less time spent on physical activity and shorter sleep duration represent other important behavioural factors that have also been implicated in the aetiology of childhood obesity[9,10]. From a public health perspective, these associations are very important, since identification of lifestyle patterns that are strongly related to an increased risk of obesity could potentially facilitate the formation of practical public health advice specifically targeted at the prevention and management of childhood obesity. Several previous studies have investigated the association between dietary patterns and childhood obesity; however, to the best of our knowledge, no previous study has set out to examine, concurrently, the possible role of specific lifestyle and dietary behavioural patterns in the rise of childhood prevalence.

Therefore the aim of the current study was to concurrently examine, for the first time, specific lifestyle and dietary patterns of behaviour associated with increased adiposity in children.

Methods

Sampling

The Healthy Growth Study was a large-scale cross-sectional epidemiological study which was started in May 2007. Approval to conduct the study was granted by the Greek Ministry of National Education and the Ethics Committee of Harokopio University of Athens, and the study was conducted in accordance with the ethical standards specified in the 1964 Declaration of Helsinki. The study population comprised schoolchildren aged 9–13 years old, attending the 5th and 6th grades of primary schools located in municipalities within the counties of Attica, Aitoloakarnania, Thessaloniki and Iraklio. The sampling of schools was random, multistage and stratified by parents' educational level and total population of students attending schools within municipalities of these counties, as described in more detail elsewhere[11]. The study population was representative of the 9–13-year-old schoolchildren living in the four counties included in the study. Nevertheless, these counties are scattered throughout the Greek territory, covering the northern (i.e. Thessaloniki), central (i.e. Attica), western (i.e. Aitoloakarnania) and southern (i.e. Iraklio, Crete) parts of Greece. This, combined with the random, multistage and stratified sampling procedures followed to recruit the sample, are indicative of the representativeness of the study population. The sampling procedure yielded seventy-seven primary schools, representative of the total number of schools in the counties under study, which responded positively when they were invited to participate in the study. An extended letter explaining the aims of the study and a consent form for taking full measurements were provided to all parents or guardians having a child in these schools. Parents who agreed to the participation of their children in the study had to sign the consent form and provide their contact details. Signed parental consent forms were collected for 2656 out of 4145 children (response rate 64·1 %).

Dietary intake

Dietary intake data were obtained by trained dietitians and nutritionists via three 24 h recall morning interviews (i.e. two consecutive weekdays and one weekend day) conducted with children at the school site. Specifically, all study participants were asked to describe the type and amount of foods and beverages consumed during the previous day, provided that it was a usual day according to the participant's perception. To improve the accuracy of food description, standard household measures (cups, tablespoons, etc.) and food models were used to define amounts. At the end of each interview, the interviewers, who were dietitians rigorously trained to minimize the interviewer effect, reviewed the collected data with the respondent in order to clarify entries, servings and possible forgotten foods. Food intake data were analysed using the Nutritionist V diet analysis software version 2·1, which was extensively amended to include traditional Greek recipes[12]. Furthermore, the database was updated with nutritional information of processed foods provided by independent research institutes, food companies and fast-food chains.

The food-grouping scheme was designed for all foods or entries (core and recipe) appearing in Nutritionist V. In total, forty-seven food groups were initially established, based on similar source characteristics and nutrient content. Composite food items, such as recipes, were analysed and were assigned to food groups according to primary ingredients. A similar methodology for the extraction of food groups was previously reported in studies with a smaller sample size, but with only one 24 h recall available[13]. Examples of foods included in the food groups were documented previously[14]. In total, eighteen large food categories (wholegrain bread and cereals; refined bread and cereals; dairy products; vegetables; fruits; red meat; processed meat; eggs; potatoes; legumes; fish; other seafood; white meat; fats and oils; fresh fruit juices; sugared beverages (i.e. soft drinks and packed fruit juices); salty snacks; and sweets) were created and the relevant values were calculated as consumption in grams per day.

Breakfast and meal frequency patterns

Although there is still no widely acceptable definition for breakfast, it has been proposed that an ideal breakfast is the one that would typically include as the first meal of the day choices from the following three food groups: milk and milk-derived products; cereals (preferably whole grain); and fruits (fresh fruits or natural juices; no sugar)[15]. Using data from the 24 h recalls and on the basis of the aforementioned definition of an ideal breakfast, a categorical variable was developed to assess the adequacy of children's breakfast consumption. More specifically, the following categories were created: 0 = salty, sweet or other savoury snacks; 1 = zero portions of dairy products, cereals and fruits; 2 = one portion of dairy products or cereals or fruits; 3 = one portion of dairy products and one portion of cereals or fruits; and 4 = one or more portions of dairy products, cereals and fruits. Data from 24 h dietary recalls were also used to define meal frequency. In turn, meal frequency (i.e. number of meals per day) was assessed by summing the number of meals in which any portion of food was consumed.

Physical activity levels

Physical activity during leisure time was assessed using a standardized activity interview, based on a questionnaire completed by the participants in the presence of a member of the research team. Further details regarding the reliability and validity of the questionnaire are provided elsewhere[16]. Respondents reported the time spent on various physical activities on two weekdays and one weekend day, most preferably Sunday. Reported activities were grouped by a member of the research team into moderate-to-vigorous physical activity (MVPA; intensity higher than 4 MET (metabolic equivalents)), including activities such as brisk walking, bicycling, gymnastics, dancing, basketball, soccer, athletics, tennis, swimming, skipping and general participation in active outdoors games. Given the age group, MVPA was defined as continuous physical activities causing sweating and heavy breathing for periods longer than 15 min, but with occasional breaks in intensity, rather than the strict aerobic definition of twenty continuous minutes appropriate for adults. The other level of physical activity that was assessed in the present study was defined as 'light' (i.e. intensity lower than 4 MET). Physical activity levels that have been proposed to positively affect cardiorespiratory function and to produce desirable health outcomes (i.e. better weight, glycaemic, lipidaemic control, etc.) are those being higher than 4 MET and correspond to MVPA[17]. Finally, the average weekdays and weekend time (h/d) spent on sedentary activities and more specifically on watching television/DVD/videos and/or recreational usage of games consoles/computer was defined as screen time.

Anthropometry

Participants underwent a physical examination by two trained members of the research team. The protocol and equipment used were the same in all schools. Weight was measured to the nearest 10 g using a digital scale (Seca Alpha, model 770; Seca, Hamburg, Germany). Children were weighed without shoes in the minimum clothing possible. Height was measured to the nearest 0·1 cm using a commercial stadiometer (Leicester Height Measure; Invicta Plastics, Oadby, UK) with the child standing barefoot, keeping shoulders in a relaxed position, arms hanging freely and head in the Frankfurt horizontal plane. Weight and height were used to calculate BMI using Quetelet's equation: weight (kg)/[height (m)]^2. The International Obesity Taskforce cut-off points[18,19] were used to categorize participants as 'underweight', 'normal weight', 'overweight' or 'obese'. Waist circumference (WC) was measured to the nearest 0·1 cm with the use of a non-elastic tape (Hoechstmass, Sulzbach, Germany) with the child standing, at the end of a gentle expiration, after placing the measuring tape on a horizontal plane around the trunk, at the level of the umbilicus, midway between the lower rib margin and the iliac crest. The age- and sex-specific WC percentiles were used for the classification of central obesity (≥90th percentile)[20]. Furthermore, one well-trained and experienced female paediatrician in each prefecture determined pubertal maturation (Tanner stage) after thorough visual inspection of breast development in girls and genital development in boys[21].

The thickness of four skinfolds (triceps, biceps, subscapular and suprailliac) was measured to the nearest 0·1 mm to the right side of the body with a Lange skinfold calliper (Cambridge Industries, Cambridge, MD, USA). Each skinfold was grasped gently, in order to avoid causing any unnecessary discomfort to the child. Triceps and biceps skinfold thickness was measured with the right arm hanging relaxed at the side of the body. The skinfold was picked up about 1 cm bellow the midpoint mark over the triceps and biceps muscle, respectively. Measurement of the subscapular skinfold thickness was performed while the child stood with shoulders relaxed and after identifying the inferior angle of the scapula. The skinfold was picked up 1 cm below the subscapular mark. Suprailliac skinfold was measured just above the iliac crest, along the axis of the anterior line. In each case the calliper was applied to the 'neck' of the fold just above the finger and thumb, for two repeated measurements.

Assessment of percentage body fat and visceral fat mass

Bioelectrical impedance analysis (BIA) was used for the assessment of percentage body fat (Akkern BIA 101; Akkern Srl, Florence, Italy) and for abdominal/visceral fat mass (Tanita Viscan AB-140, Kowloon, Hong Kong). In abdominal BIA an electric current is passed between the regions near the umbilicus and spinal cord at the umbilicus level and the voltage generated in the lateral abdomen is recorded. Because the equipotential line that passes through visceral fat appears on the lateral abdominal surface, the amount of visceral fat can be estimated by measurement of the voltage generated at this location using a regression equation determined by computed tomography[22]. Participants were instructed to abstain from any food or liquid intake and from any intensive exercise for 4 h before measurement. They were also instructed not to wear any metal object during measurement. The assessments took place with the study participants lying on a non-conductive surface at ambient room temperature. Percentage body fat was calculated from the resistance and reactance values using valid equations derived from a similar pre-adolescent population[23], while percentage trunk fat mass and visceral fat rating (rating scale from 1 to 59 units, with 0·5 increment) were read directly from the instrument. As there were only two Tanita Viscan devices available, data on trunk-visceral fat mass were collected for a representative sub-sample of 1500 children.

Socio-economic, perinatal and other information collected from parents

Data on the socio-economic background of the families having at least one child participating in the study were collected from the parents (most preferably from the mother) during scheduled face-to-face interviews at school. For those parents not being able to attend the meetings (approximately 5 % of the total sample), data were collected via telephone interviews. All interviews were conducted by members of the research team who were rigorously trained to minimize the interviewer effect by using a standardized questionnaire. The socio-economic data collected from parents included: parental educational level (years of education); home size (m^2); number of family members living at home; number of cars owned by the family; and home property ownership. All aforementioned data were grouped, scored and combined for the development of a socio-economic status (SES) index as follows: scores of 0, 1, 2 and 3 were assigned to <9, 9–12, 12–16 and >16 years of maternal and paternal education, respectively; scores of 0, 1, 2 and 3 were assigned to <20, 20–25, 25–30 and >30 home m^2 per family member, respectively; scores of 0, 1, 2 and 3 were assigned to 0, 1, 2 and ≥3 cars owned by the family, respectively; and scores of 0 and 1 were assigned to rented or owned home, respectively. The total score of the SES index, obtained by summing the scores from each index component, had values ranging between 0 and 13 and with higher values indicating higher SES of the family. Data on self-reported weight and height of the mother and the father were also recorded. Furthermore, during the interviews parents were also asked to bring with them their child's birth certificate and medical record from which birth date (this was used for estimation of the exact age of each child) and birth weight were recorded. Finally, parents were also asked to report their children's nightly sleep duration, which was calculated by asking parents the time their children usually go to bed at night and the time they usually wake up in the morning on weekdays and on weekend days, separately.

Statistical analysis

Lifestyle component derivation

PCA was used to identify the lifestyle patterns. PCA is a multivariate technique that can evaluate intercorrelations between individual predictor variables and results in the extraction of uncorrelated components (i.e. lifestyle patterns). The Kaiser–Meyer–Olkin (KMO) criterion and Bartlett's test of sphericity were used to assess the suitability of the data for PCA. An overall KMO criterion close to unity means that the data set is suitable for PCA. The orthogonal rotation (varimax option) was used to derive optimal non-correlated components (lifestyle patterns). The number of components that can be extracted is equal to the number of predictor variables. To decide the number of components to retain, the Kaiser criterion and the scree plot (eigenvalues >1) were used. Factor loadings represent the correlations of each predictor with the lifestyle pattern score. Higher absolute values of factor loadings indicate that the predictor contributes most to the construction of this particular component (Table 2). The lifestyle components (patterns) were named according to the factor loadings of dietary, physical activity or sleep behaviours correlated most with the component (factor loadings >|0·4|).

Descriptive and other statistical analyses

Categorical values were presented as frequencies. Associations between categorical variables were examined by using the χ^2 test and the two-sample z test for proportions whenever appropriate. Multiple linear regression analysis was used to evaluate the associations between body fat mass indices and lifestyle patterns derived from PCA, which were treated as continuous variables after testing for linearity (Table 4). More specifically, three different models were applied: Model 1 was unadjusted; Model 2 adjusted for sex and Tanner stage; and Model 3 adjusted for sex, Tanner stage, mean parental BMI, SES index score and birth weight. The results from the linear regression models are presented as standardized beta coefficients (β). Moreover, participants' lifestyle component scores were categorized into quartiles so that, for each lifestyle component, the fourth quartile consisted of persons whose dietary, physical activity and sleep behaviours were adherent most to that particular pattern. Based on the statistically significant relationships provided by the linear regression models tested, logistic regression analysis was further performed to evaluate the association between the quartiles of each lifestyle component and the probability of being overweight or of having increased fat mass levels. The results of logistic regression models were presented as odds ratios and 95 % confidence intervals (Table 5).

https://doi.org/10.1017/S1368980013000323 Published online by Cambridge University Press

Table 1 Descriptive characteristics of the study population: schoolchildren aged 9–13 years (*n* 2073) participating in the Healthy Growth Study

	Boys (*n* 1032)		Girls (*n* 1041)		Total (*n* 2073)	
	%		%		%	
Weight status						
Underweight	2·2		3·7		2·9	
Normal weight	53·7†		58·2		56·0	
Overweight	30·9		28·8		29·9	
Obese	13·2†		9·3		11·2	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	11·2	0·7	11·2	0·7	11·2	0·7
Weight (kg)	45·3	11·0	45·0	10·9	45·2	10·9
Height (cm)	148·2*	7·4	149·1	8·1	148·7	7·8
BMI (kg/m^2)	20·5*	3·9	20·1	3·7	20·3	3·8
Waist circumference (cm)	69·9*	9·9	67·5	9·0	68·7	9·6
Sum of skinfold thicknesses (mm)	53·8*	24·7	56·0	21·0	54·9	23·0
Fat mass (%)	28·6*	9·2	29·7	9·1	29·2	9·2
Trunk fat (%)‡	20·0*	7·0	25·3	7·9	22·7	7·9
Visceral trunk fat rating‡	5·6*	3·7	4·0	2·2	4·8	3·2

*Mean values were significantly different from those of girls (Student's *t* test): $P<0·05$.
†Proportions were significantly different from those of girls (based on the χ^2 test and the two-sample *z* test): $P<0·05$.
‡Trunk and visceral fat mass data were available for 1211 children.

Data were analysed using the statistical software package SPSS version 13·0. In all statistical analyses, the level of significance was set at $P<0·05$.

Results

A complete set of socio-economic, demographic, parental BMI, family status, perinatal, clinical, anthropometric and body composition data were collected for 2073 children (49·8 % boys and 50·2 % girls) from the 2665 children whose parents had provided signed consent forms. The attrition was attributed to the inclusion in the parental questionnaire of questions relating mainly to certain components of the SES index (i.e. number of cars, home m^2 and home property ownership) during the course of the study. However, the sample of 2073 children participating in the current study was adequate to provide the required statistical power needed for the analysis of the data. Table 1 illustrates that the total prevalence of overweight and obesity was 29·9 % and 11·2 %, respectively, with a significantly higher prevalence of obesity in boys than in girls (13·2 % *v.* 9·3 %, $P<0·05$). Furthermore, BMI, WC and visceral trunk fat rating were higher in boys than in girls ($P<0·05$). On the other hand, height, sum of skinfold thicknesses, percentage fat mass and percentage trunk fat mass were significantly higher in girls than in boys ($P<0·05$).

Table 2 summarizes the factor loadings of the factors retained from the PCA. From the initial eighteen food groups, seven were included in the PCA as these were strongly intercorrelated with each other. The value of the KMO criterion was equal to 0·6 and the *P* value for Bartlett's test of sphericity was <0·001, indicating that the lifestyle variables entered in the analysis were strongly intercorrelated and that PCA could be correctly used for assessing 'healthy' or 'unhealthy' patterns. PCA analysis indicated five different lifestyle components explaining 52·7 % of the total variance with regard to the examined variables. These components were defined as follows: higher dairy consumption and more adequate breakfast (component 1); higher consumption of high-fibre foods (component 2); more screen time, less sleep time and higher consumption of sugared beverages (component 3); more time spent on MVPA and more frequent meals (component 4); higher red meat and lower fish consumption (component 5).

Table 3 displays the descriptive characteristics of the dietary and lifestyle variables included in the PCA for the total sample and by gender. Regarding gender differences, boys were found to have significantly higher consumption of dairy products and sugared drinks as well as more time spent on MVPA compared with girls ($P<0·05$). No other statistically significant gender differences were observed.

Table 4 presents the associations, derived from the three different models of the linear regression analyses, between anthropometric (i.e. BMI, WC and sum of skinfold thicknesses) as well as BIA fat mass indices and each one of the five lifestyle components. In the case of the anthropometric indices, lifestyle components 1 and 4 were negatively associated with BMI and WC, even after adjusting for several potential confounders in Model 3 ($\beta=-0·057$, $P=0·007$ and $\beta=-0·049$, $P=0·024$ respectively for BMI; $\beta=-0·058$, $P=0·007$ and $\beta=-0·055$, $P=0·012$ respectively for WC). The sum of skinfold thicknesses was also negatively associated with lifestyle component 1 ($\beta=-0·084$, $P<0·001$) and lifestyle component 2 ($\beta=-0·069$,

https://doi.org/10.1017/S1368980013000323 Published online by Cambridge University Press

Table 2 Factor loadings derived from principal component analysis conducted with dietary and lifestyle variables available for schoolchildren aged 9–13 years (*n* 2073) participating in the Healthy Growth Study

	Component				
Predictor	1	2	3	4	5
Dairy consumption‡	0·79∥∥	0·15	−0·11	0·10	0·002
Fruit consumption	0·05	0·62∥∥	−0·01	0·15	0·000
Vegetable consumption	−0·05	0·74∥∥	0·11	−0·04	0·04
Wholegrain products consumption§	0·11	0·50∥∥	−0·22	−0·09	−0·11
Red meat consumption	0·01	−0·06	0·07	0·12	0·72∥∥
Fish consumption	−0·01	−0·01	0·07	0·11	−0·75∥∥
Sugared drinks consumption∥	−0·17	−0·15	0·56∥∥	0·36	0·11
Adequate breakfast consumption	0·76∥∥	−0·09	−0·02	−0·13	0·03
Meal frequency	0·45∥∥	0·35	0·12	0·48∥∥	−0·04
Screen time¶	0·04	−0·06	0·68∥∥	−0·21	−0·02
Time spent on physical activity‡‡	−0·04	−0·004	−0·12	0·82∥∥	−0·001
Sleep time§§	0·03	−0·07	−0·58∥∥	0·01	0·03
Explained variance (%)	12·1	11·4	10·2	9·7	9·3

‡Consumption of milk, yoghurt and cheese.
§Consumption of wholegrain bread and cereal.
∥Consumption of regular soft drinks and sugared fruit juices.
¶Time spent watching television/DVD/videos and/or using games consoles/computer for fun.
‡‡Time spent on moderate-to-vigorous physical activity.
§§Nightly sleep time on weekdays.
∥∥Predictor with the highest factor loading (>|0·4|) within the component.

Table 3 Descriptive characteristics of the dietary and lifestyle variables included in the principal component analysis

	Boys (*n* 1032)		Girls (*n* 1041)		Total (*n* 2073)	
	Median	P25–P75	Median	P25–P75	Median	P25–P75
Dairy consumption (g/d)‡	387·8*	258·0–536·0	349·3	223·5–516·0	373·9	244·6–526·1
Fruit consumption (g/d)	59·0	0·0–138·0	59·0	0·0–138·0	59·0	0·0–138·0
Vegetable consumption (g/d)	56·8	7·6–126·7	56·8	12·6–113·5	56·8	10·0–120·1
Wholegrain consumption (g/d)§	10·0	0·0–16·5	9·6	0·0–15·8	10·0	0·0–16·2
Red meat consumption (g/d)	45·0	0·0–94·6	45·0	0·0–80·0	45·0	0·0–90·0
Fish consumption (g/d)	18·0	0·0–35·4	18·7	0·0–36·7	18·3	0·0–36·2
Sugared drinks consumption (ml/d)∥	85·2*	0·0–167·5	62·1	0·0–126·9	73·3	0·0–131·6
Screen time (h/d)¶	2·0	1·3–3·0	2·0	1·3–3·0	2·0	1·3–3·0
Time spent on physical activity (min/d)‡‡	67·1*	32·1–117·7	45·4	17·1–85·7	55·7	25·0–100·7
Sleep time (h/d)§§	9·0	8·5–9·3	9·0	8·5–9·3	9·0	8·5–9·3
	n	%	*n*	%	*n*	%
Adequate breakfast consumption						
Salty and sweet snacks and other	86	8·3	92	8·8	178	8·6
0 portions of fruits, cereals or dairy products	209	20·3	232	22·3	441	21·3
1 portion of fruits, cereals or dairy products	482	46·7	491	47·1	973	46·9
2 portions of fruits, cereals or dairy products	218	21·1	187	17·9	405	19·5
3 or more portions of fruits, cereals or dairy products	37	3·6	40	3·8	77	3·7
Meal frequency						
2 meals/d	5	0·5	9	0·9	14	0·7
3 meals/d	83	8·0	71	6·8	154	7·4
4 meals/d	266	25·8	293	28·1	559	27·0
5 meals/d	450	43·6	481	46·2	931	44·9
6 meals/d	228	22·1	188	18·0	416	20·1

P25, 25th percentile; P75, 75th percentile.
*Median values were significantly different from those of girls (non-parametric Mann–Whitney test): $P<0·05$.
‡Consumption of milk, yoghurt and cheese.
§Consumption of wholegrain bread and cereal.
∥Consumption of regular soft drinks and sugared fruit juices.
¶Time spent watching television/DVD/videos and/or using games consoles/computer for fun.
‡Time spent on moderate-to-vigorous physical activity.
§§Nightly sleep time on weekdays.

$P=0·002$) after multiple adjustments were made in Model 3. Regarding BIA fat mass indices, percentage fat mass was negatively associated with lifestyle components 1 and 4 ($\beta=-0·048$, $P=0·029$ and $\beta=-0·083$, $P<0·001$ respectively) and percentage trunk fat mass was negatively associated with lifestyle component 4 ($\beta=-0·085$, $P=0·002$) after adjusting for potential confounders in Model 3.

Table 4 Single (Model 1) and multiple (Models 2 and 3) linear regression analysis examining the association of lifestyle components with anthropometric and total, trunk and visceral fat mass indices in schoolchildren aged 9–13 years (*n* 2073) participating in the Healthy Growth Study

	Model 1		Model 2		Model 3	
Component	β	*P* value	β	*P* value	β	*P* value
BMI (kg/m^2)						
Lifestyle component 1	−0·06	0·010	−0·06	0·005	−0·06	0·007
Lifestyle component 2	−0·01	0·722	−0·01	0·702	0·01	0·737
Lifestyle component 3	0·08	<0·001	0·05	0·040	0·04	0·057
Lifestyle component 4	−0·06	0·005	−0·06	0·010	−0·05	0·024
Lifestyle component 5	−0·03	0·248	−0·02	0·444	−0·01	0·627
Waist circumference (cm)						
Lifestyle component 1	−0·06	0·008	−0·06	0·003	−0·06	0·007
Lifestyle component 2	−0·03	0·139	−0·04	0·103	−0·02	0·310
Lifestyle component 3	0·08	<0·001	0·04	0·043	0·04	0·075
Lifestyle component 4	−0·06	0·012	−0·07	0·003	−0·06	0·012
Lifestyle component 5	0·002	0·922	0·001	0·953	0·01	0·703
Sum of skinfold thicknesses (mm)						
Lifestyle component 1	−0·09	<0·001	−0·09	<0·001	−0·08	<0·001
Lifestyle component 2	−0·08	<0·001	−0·08	<0·001	−0·07	0·002
Lifestyle component 3	0·04	0·080	0·02	0·299	0·02	0·353
Lifestyle component 4	−0·06	0·004	−0·05	0·034	−0·04	0·071
Lifestyle component 5	−0·03	0·182	−0·02	0·274	−0·02	0·338
Fat mass (%)						
Lifestyle component 1	−0·05	0·023	−0·05	0·028	−0·05	0·029
Lifestyle component 2	−0·04	0·084	−0·04	0·112	−0·02	0·307
Lifestyle component 3	0·03	0·249	0·003	0·881	0·003	0·894
Lifestyle component 4	−0·11	<0·001	−0·09	<0·001	−0·08	<0·001
Lifestyle component 5	−0·04	0·113	−0·02	0·314	−0·02	0·299
Trunk fat (%)‡						
Lifestyle component 1	−0·06	0·034	−0·05	0·060	−0·04	0·152
Lifestyle component 2	−0·004	0·899	0·01	0·721	0·02	0·528
Lifestyle component 3	0·08	0·005	0·06	0·024	0·05	0·063
Lifestyle component 4	−0·16	<0·001	−0·09	0·001	−0·09	0·002
Lifestyle component 5	−0·13	<0·001	−0·08	0·002	−0·03	0·084
Visceral trunk fat rating‡						
Lifestyle component 1	−0·04	0·151	−0·06	0·028	−0·04	0·058
Lifestyle component 2	0·01	0·769	−0·001	0·984	0·01	0·713
Lifestyle component 3	0·08	0·008	0·06	0·037	0·04	0·130
Lifestyle component 4	0·01	0·839	−0·04	0·146	−0·03	0·280
Lifestyle component 5	−0·04	0·213	−0·06	0·034	−0·05	0·095

β, standardized beta coefficient.
Model 1, unadjusted; Model 2, adjusted for Tanner stage and sex, Model 3, adjusted for sex, Tanner stage, parental BMI, socio-economic status index and birth weight.
Lifestyle component 1, higher dairy consumption and more adequate breakfast; lifestyle component 2, higher consumption of high-fibre food (i.e. fruits, vegetables and wholegrain food); lifestyle component 3, more screen time, shorter sleep duration and higher consumption of sugared beverages; lifestyle component 4, more time spent on moderate-to-vigorous physical activity and more frequent meals; lifestyle component 5, higher red meat consumption and lower fish consumption.
‡Trunk and visceral fat mass data were available for 1211 children.

Logistic regression analyses summarized in Table 5 showed that children whose lifestyle conformed most closely to patterns of lifestyle component 1 (i.e. children with dairy and breakfast consumption patterns within the fourth quartile) were 39·4 %, 45·2 % and 32·2 % less likely to be overweight/obese and in the highest quartile of sum of skinfold thicknesses and percentage fat mass, respectively, than children whose lifestyle was different from this pattern (i.e. children within the first quartile), after controlling for several potential confounders. Furthermore, children in the fourth quartile of lifestyle component 2 (i.e. children with the highest consumption of high-fibre foods) were 27·4 % less likely to be in the highest quartile of sum of skinfold thicknesses than children in the first quartile of lifestyle component 2. Finally, children in the fourth quartile of lifestyle component 4 (i.e. children who spent more time on physical activity and had more frequent meals) were 38·0 %, 26·3 % and 29·5 % less likely to be overweight, centrally obese and in the highest quartile of percentage fat mass than their peers in the first quartile of lifestyle component 4.

Discussion

The present study showed considerably high rates of overweight (29·9 %) and obesity (11·2 %) in a representative sample of Greek children which are two- to threefold higher compared with the prevalences reported for children in central and northern European countries[24].

https://doi.org/10.1017/S1368980013000323 Published online by Cambridge University Press

Table 5 Logistic regression analyses examining the association of quartiles of lifestyle components (independent variable) with anthropometric and total, trunk and visceral fat mass indices (dependent variables) in schoolchildren aged 9–13 years (*n* 2073) participating in the Healthy Growth Study

	Quartile of lifestyle component 1 (higher dairy consumption and more adequate breakfast)						
	First	Second		Third		Fourth	
	(ref.)	OR	95 % CI	OR	95 % CI	OR	95 % CI
Overweight/obesity	1·00	0·82	0·63, 1·07	0·94	0·73, 1·23	0·61	0·46, 0·79
Central obesity	1·00	0·85	0·60, 1·22	0·76	0·53, 1·09	0·92	0·65, 1·31
Sum of skinfold thicknesses, fourth quartile	1·00	0·74	0·55, 0·98	0·66	0·49, 0·88	0·55	0·41, 0·74
Percentage fat mass, fourth quartile	1·00	0·88	0·66, 1·18	0·86	0·64, 1·15	0·68	0·50, 0·92
	Quartile of lifestyle component 2 (higher consumption of high-fibre food)						
	First	Second		Third		Fourth	
	(ref.)	OR	95 % CI	OR	95 % CI	OR	95 % CI
Sum of skinfold thicknesses, fourth quartile	1·00	1·07	0·80, 1·42	0·71	0·53, 0·96	0·73	0·54, 0·98
	Quartile of lifestyle component 4 (more time spent on physical activity and more frequent meals)						
	First	Second		Third		Fourth	
	(ref.)	OR	95 % CI	OR	95 % CI	OR	95 % CI
Overweight/obesity	1·00	0·84	0·65, 1·09	0·65	0·50, 0·84	0·62	0·48, 0·81
Central obesity	1·00	1·04	0·75, 1·46	0·53	0·36, 0·78	0·74	0·52, 0·99
Percentage fat mass, fourth quartile	1·00	0·94	0·71, 1·25	0·55	0·40, 0·75	0·71	0·52, 0·95
Percentage trunk fat, fourth quartile‡	1·00	1·25	0·86, 1·83	0·60	0·40, 1·04	0·80	0·53, 1·22

ref., reference category.
Adjusted for sex, Tanner stage, parental BMI, socio-economic status index and birth weight.
‡Trunk and visceral fat mass data were available for 1211 children.

Most importantly, the current study identified five different lifestyle components, which were associated not only with overweight/obesity in children but also with increased fat mass levels. This is important considering that anthropometric indices of adiposity (i.e. BMI, WC, skinfold thicknesses) are usually subjected to more bias than other techniques that are used to assess body composition, such as BIA[25].

Lifestyle component 1 comprised of higher dairy consumption and more adequate breakfast was negatively associated with BMI, WC, sum of skinfold thicknesses and percentage fat mass. The results of the present study also indicated that the children who tended to conform most closely to the pattern of higher dairy and adequate breakfast consumption (i.e. in the fourth quartile) were less likely to be overweight and to have increased fat mass levels. Dairy consumption is one of the best sources of highly bioavailable dietary Ca, which has been independently associated with reduced body weight[26–28]. More specifically, increased dietary Ca intake inhibits secretion of parathyroid hormone, which in turn lowers Ca influx within the adipocytes[29]. It has been suggested that increased intracellular Ca concentration may stimulate lipogenesis, inhibit lipolysis and reduce thermogenesis, alterations that if sustained for a long period can lead to fat mass accumulation and obesity[30]. In this context a previous study, which evaluated the association between dietary patterns and obesity among women, showed that consumption of low-fat dairy products was related with lower odds of obesity[31]. Still, it is not safe to claim that increasing the consumption of dairy foods results in a reduction in body weight or fat mass levels[32]. Regarding breakfast consumption, a previous study which attempted to identify the possible interactions between lifestyle patterns and BMI revealed that a pattern also comprised of regular breakfast consumption was inversely associated with excess body weight in children[6]. Furthermore, other studies have shown that regular consumption of breakfast that comprises dairy products, cereals and fruits is associated with a lower risk of overweight among children[33–35]. As breakfast consumption is generally considered as a healthy dietary behaviour[36], children who skip breakfast have a greater likelihood of reporting higher energy intake from high-fat, salty and sweet snacks at main meals[37]. Furthermore, breakfast omission seems to favour excessive hunger and rebound overeating[38], which may lead to higher energy intake.

The current study also showed that lifestyle component 2, comprising consumption of high-fibre foods such as fruits, vegetables and wholegrain products, was negatively associated with the sum of skinfold thicknesses, probably due to the higher satiety induced by consumption of these foods[39]. Two other studies performed in Greece and in Great Britain also revealed a negative association between a dietary pattern comprising high-fibre food consumption and excess adiposity in children[6,40]. Other recent research has shown that fibre supplementation in obese individuals can significantly enhance weight loss[41]. Soluble fibre, when fermented in the large intestine, induces production of glucagon-like peptide-1 and peptide YY, two gut hormones that stimulate satiety. Furthermore, increased dietary fibre intake is inversely related to total energy intake, as well as to the diet's metabolizable energy, i.e. gross energy intake minus the energy lost in the faeces, urine and combustible gases[42]. However, further to the physiological mechanisms described above, higher consumption of dairy products, wholegrain cereals, fruits and vegetables could also support the maintenance of lower body weight and fat mass levels since these food groups reflect an overall healthier diet, which is very common among normal-weight individuals.

The findings of the present study further indicated that lifestyle component 4, defined by a combination of more time spent on MVPA and more frequent meals during the day, was negatively associated with BMI, WC, and percentage total body and trunk fat mass. There is plenty of evidence that both physical activity and frequent meals *per se* are negatively correlated with overweight and obesity in childhood[43–46]. A possible explanation for this negative association is that these behaviours are associated with an increased energy expenditure. Regarding physical activity, energy is required for the mechanical work associated with muscle contraction[47]. However, in a previous study when physical activity was clustered in lifestyle patterns no association was found with BMI[6]. As far as meals are concerned, more frequent meal consumption seems to increase diet-induced thermogenesis, thus leading to higher energy expenditure[48]. The importance of consuming frequent meals for maintaining a normal body weight has also been highlighted by other studies, concluding that obese children should be encouraged to eat three main meals and two snacks per day (breakfast, lunch, afternoon meal, dinner, supper)[49].

A number of strengths and limitations can be identified in the present study. Regarding strengths, the Healthy Growth Study was a large-scale epidemiological study conducted using a representative sample of children from four prefectures within the wider region of Greece. Furthermore, the adjustments for specific confounders resulted in the extraction of more accurate results from the linear and logistic regression analyses. However, one of the main limitations of the study is that due to its cross-sectional design it cannot support causal relationships between lifestyle patterns and body composition indices. Another limitation of the study is that the PCA method could not specify how many servings of dairy foods or how many meals one should consume to get the required health benefits. Finally, trunk and visceral fat mass data were available only for 1211 children from the 2073 children initially examined.

The findings of the current study are indicative of strong associations between certain lifestyle patterns and adiposity-related indices in children. More specifically, various anthropometric and bioelectrical impedance indices of fat mass were negatively associated with the following three dietary and lifestyle behavioural patterns identified in the present study: (i) increased dairy food and breakfast consumption; (ii) increased consumption of high-fibre foods; and (iii) more time engaged in MVPA concurrently with an increased number of meals consumed per day. These findings could facilitate advice targeting children and their families and the identified lifestyle patterns should be considered as components of future childhood obesity prevention initiatives.

Acknowledgements

Source of funding: This research was co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Programme 'Education and Lifelong Learning' of the National Strategic Reference Framework (NSRF) Research Funding Program: 'Heracletus II. Investing in knowledge society through the European Social Fund'. *Conflicts of interest:* None of the authors has any conflict of interest to declare. *Authors' contributions:* Y.M., G.M., C.L. and G.P.C. contributed to the study design. All authors contributed to the writing and revising of the manuscript. G.M. and Y.M. were responsible for data collection, management and statistical analyses. *Acknowledgements:* The authors would like to thank members of the Healthy Growth Study Group for their valuable contribution to the completion of the study.

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