

# A sustainability of a multi-component education program (ABC of Healthy Eating) after three months and nine months: the socioeconomic context in improving nutrition knowledge in Polish teenagers

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## Research

**Keywords:** Adolescence, Education, Intervention, Nutrition knowledge, Social factors

**Posted Date:** March 30th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-336420/v1>

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# Abstract

**Background:** Nutrition knowledge, through its direct influence on dietary behaviours, can be considered as an important factor that indirectly influences human health. Dietary behaviours are formed in childhood, and many of them are relatively stable over time. It follows that changing dietary behaviours and developing nutrition knowledge should take place before undesirable dietary habits become established. The study aimed to evaluate the sustainability of a multi-component education (ABC-HEat) program related to healthy nutrition and lifestyle after three months and nine months and to assess the socioeconomic context in improving teenage nutrition knowledge.

**Methods:** The study was designed as a clustered, controlled, education-based intervention. A sample was chosen and allocated into either an educated group (under intervention) or a control group (outside of intervention). The study covered 464 students 11-12-year-old (educated/control 319/145) from primary schools in locations covering the entire territory of Poland. In the educated group, data were collected three times: before education, after three months and after nine months to measure the short- and the long-term effect of education, respectively. In the control group, data were collected in parallel. Changes in nutrition knowledge score (NKS, points) by sex, residence, family affluence scale (FAS) were the main outcome measures. Logistic regression models were used to evaluate chance of no increase in the NKS with two reference categories: any increase or an increase by  $\geq 4$  points.

**Results:** The increase in the NKS was significantly higher in the educated group than in the control group – three months after education on average by 1.4 to 2.7 points (all  $P < 0.001$ ) in the total sample and all subgroups (girls, boys, rural residence, urban residence, low FAS, higher FAS), and nine months after education in rural residents by 2.2 points ( $P < 0.001$ ) and in the total sample by 0.4 ( $P < 0.05$ ). In the educated group, the chance of no increase in the NKS was higher in urban than rural residents after three months and nine months (adjusted odds ratios [OR] and 95% Confidence Intervals [95% CI]: 3.63, 1.80-7.31 and 2.99, 1.60-5.59, respectively, both  $P < 0.001$ ) using the increase in the NKS by  $\geq 4$  points as a reference.

**Conclusions:** The multi-component education program improved the nutrition knowledge of teenagers in the short-term regardless of socioeconomic variables, but in the long-term this effect was visible only in rural residents. It suggests that a special path of nutrition education addressed to urban teens may be required.

## Introduction

Nutrition knowledge forms the basis for shaping attitudes towards foods, nutrition and health and human dietary behaviours [1, 2, 3]. Nutrition knowledge, through its direct influence on dietary behaviours, can be considered as an important factor that indirectly influences human health. Dietary behaviours are formed in early childhood [4, 5] and change throughout the lifespan but key habits and food preferences are relatively stable over time, e.g. craving for sweets or a tendency to over-consume fats [6, 7, 8]. It follows that changing dietary behaviours and developing nutrition knowledge should take place in childhood and adolescence before undesirable dietary habits become established.

The effectiveness of nutrition education depends on many factors, including the content of the program, its goals and duration and the method used that should be adapted to the developmental age of respondents, their perceptive abilities and needs [9, 10]. Comparative studies have shown that multi-component intervention is more effective than single-component intervention [11, 12, 13, 14], especially if it includes a practical component (e.g. workshops) combined with theoretical messages. In the Canadian program "Action Schools! BC – Healthy Eating", which used a multi-component approach with educational, environmental and family elements, a significant increase in the consumption of fresh vegetables and fruits was found [15]. This finding was confirmed in later studies [14, 16, 17, 18]. It seems that the success of the program, apart from its complexity, may depend on the complementarity of the program components, as well as the proper identification of health benefits by young people resulting from the adoption of pro-healthy dietary habits [19, 20].

The influence of socioeconomic factors on dietary and lifestyle behaviours is well known [21, 22, 23]. Many studies show that young people from families with lower socioeconomic status consume less pro-healthy foods such as vegetables and fish [1, 24, 25, 26] while more foods with lower nutrient contents but higher energy value, e.g. fast foods [27, 28, 29]. It has been suggested that the lower socioeconomic status of the family is related to the lower interest of teenagers in a pro-healthy diet [30, 31]. Therefore, it can be speculated that family socioeconomic status, determined with parents' education level, family affluence and urban vs rural residence, is an important factor influencing the nutrition knowledge level in young people. It has been shown that a poorer social environment in which young people grow up can have a devastating effect on nutrition education [32]. Therefore, socioeconomic status may determine the effectiveness of educational programs targeted at adolescents.

The impact of socioeconomic status on the nutrition knowledge level of young people and the effectiveness of nutrition- and health-related education programs has not been known so far. Filling this knowledge gap will identify inequalities in the long-term maintenance of nutrition knowledge and identify groups of children and adolescents that require a special approach when education programs are designed. The aim of the current study was to evaluate the sustainability of a multi-component education program related to healthy nutrition and lifestyle after three months and nine months and to assess the socioeconomic context in improving teenage nutrition knowledge.

## Methods

### Study design

The data for this study were collected in Poland in 2015–2016 as a part of the 'ABC of Healthy Nutrition' project, the 1st edition of the national multicentre 'ABC of Healthy Eating' (ABC-HEat) project (2015–2018) [33]. Data were collected by experienced researchers well-trained in collecting dietary data.

The study was designed as a clustered, controlled, education-based intervention. A sample was chosen and allocated (not randomly) into either an educated group (under educational intervention) or a control group (outside of educational intervention) (Fig. 1).

The study included students of selected elementary schools from urban and rural areas. The schools (not randomly selected) were located in eight locations covering the entire territory of Poland. More details on the study design and protocol were described previously by Hamulka et al. [33].

In the educated group, data were collected three times: (i) before education (at baseline), (ii) after three months ( $\pm 2$  weeks; 3-month follow-up) to measure the short-term effect of education, (iii) after nine months ( $\pm 2$  weeks; 9-month follow-up) to measure the long-term effect of education. In the control group, data were collected in parallel.

## Participants

A school class was the smallest unit in the sample selection. It was decided to start recruitment based on school classes because students were subject to the same school education and would be at a similar stage of development. Schools were first invited to take part in the study and each student of 4th- and 5th-grade classes of this school (classes that met criteria, and teachers who gave their approval) were then invited. Details of sample selection were described previously [33].

School inclusion criteria were:

- a location at a convenient distance from the academic centres (up to 50 km),
- the agreement of the school principal to school participation,
- no previous participation of the school in other nutrition-health education programs.

Participant inclusion criteria were:

- written consent of parents or legal guardians to participate,
- 4th- and 5th-grade classes of elementary school; the expected age of the students was 11–12 years at baseline;
- no disability self-declared by parent or legal guardian or teacher.

In total, 48 classes from 14 schools were selected across Poland (Fig. 1). Initially, 668 students were recruited. A total of 204 participants were excluded from analyses (17 participants because of age and 187 participants due to not attending all stages of the study). The study included 464 teenagers aged 11–12 years, 216 boys (46.6%) and 248 girls (53.4%) (Table 1).

**Determination of sample size.** Sample size was calculated using an anticipated 50% difference between the groups in the increase in nutrition knowledge score (educated group: by 30% vs. control group: by 15%) after the 9-month follow-up, including a 50% dropout rate and 10% recoding errors or missing data.

Table 1  
Sample baseline characteristics and changes in nutrition knowledge score (NKS) three months and nine months after education (% or mean and 95% confidence interval, 95% CI).

Variables	Total	Educated	Control	<i>P value</i>
Sample size	464	319	145	
Sample percentage	100.0	100.0	100.0	
Age (years), mean (95% CI)	11.9 (11.9; 12.0)	11.9 (11.9; 11.9)	12.0 (11.9; 12.0)	0.20
Gender, n (%)				0.16
Girls	248 (53.4)	178 (55.8)	70 (48.3)	
Boys	216 (46.6)	141 (44.2)	75 (51.7)	
Residence, n (%)				0.06
Urban	302 (65.1)	217 (68.0)	85 (58.6)	
Rural	162 (34.9)	102 (32.0)	60 (41.4)	
Family Affluence Scale, n (%)				
Low	117 (25.3)	79 (24.9)	38 (26.2)	0.86
Higher	345 (74.7)	238 (75.1)	107 (73.8)	
Change in NKS after 3 months, n (%)				
No increase	166 (35.9)	80 (25.1)	86 (60.1)	< 0.001
Increase by 1–3 points	177 (38.3)	130 (40.7)	47 (32.9)	
Increase by ≥ 4 points	119 (25.8)	109 (34.2)	10 (7.0)	
Change in NKS after 9 months, n (%)				
No increase	156 (33.8)	93 (29.2)	63 (44.0)	< 0.01
Increase by 1–3 points	172 (37.2)	128 (40.1)	44 (30.8)	
Increase by ≥ 4 points	134 (29.0)	98 (30.7)	36 (25.2)	
Sample size may vary in variables due to missing data.				

Family Affluence Scale (low: 0–4 points, higher: 5–7 points).

Nutrition knowledge score range: 0–18 points.

*P* – significance level of Mann-Whitney test (for means) or  $\chi^2$  test, with Yates' correction when necessary (for percentage distribution).

## Intervention

The participants of the educated group were taken over a multi-component education program lasting three weeks and covering five diet-related and lifestyle-related topics which included various forms of education, from fun to 'scientific' cognition. Each topic lasted approx. 180 min (4 h of school lessons) and was run by a minimum of 3–4 researchers. The program was developed and implemented by academic researchers. Most of the educational activities were carried out in academic centres and the rest in schools. School teachers were not involved in the education program, they were only present during educational activities. Apart from the study, students from both educated and control groups took part in regular school activities containing some content related to nutrition and a healthy lifestyle. The topics and details of the education program are presented in Table S1 and were described previously [33, 34].

## Data collection

Data related to nutrition knowledge and socioeconomic variables (self-reported) were collected with a short form of a food frequency questionnaire (acronym: SF-FFQ4PolishChildren) dedicated to school-aged children (Fig. 2). The questionnaire was developed for the 'ABC of Healthy Eating' project and its internal compatibility was tested [35].

## Nutrition knowledge

The nutrition knowledge level was determined based on eighteen questions (Table S2) [33, 34]. Participants were asked about nutrition based on questions developed by Whati et al. [36] and adapted to Polish conditions and education [33]. Correct answers were scored with 1 point and wrong or "I don't know" answers or missing data were scored with 0 points. Points were summed up for each respondent to calculate the nutrition knowledge score (NKS, in points).

## Socioeconomic data

Respondents were distinguished as rural or urban residents, based on the data collected with the questionnaire. The socioeconomic status was determined with the Family Affluence Scale (FAS) based on household characteristics (the details were described previously) [35, 37]. For international use, the scale was developed with the Health Behaviour in School-aged Children (HBSC) cross-national study. For national use, the scale was adopted by the Polish team of the

HBSC study [37]. The scale was composed of four questions related to having a family owning a car/van/truck, traveling away on holiday with the family, having a bedroom, having a family which owns computers/laptops/tablets, with answers to choose from. For each answer, points were assigned. To calculate FAS, the points were summed up for each respondent (range 0 to 7). Based on FAS distribution, the respondents were divided into two categories: low FAS (0–4 points; <25th quartile) and higher FAS (5–7 points).

## Data analysis

The normality of the distribution of continuous variables was assessed with the Shapiro-Wilk test. For continuous variables, the data were presented as means with 95% confidence interval (95% CI) while categorical variables were presented as a sample percentage (%). The differences between the means of two independent groups (educated vs. control) were verified with a Mann-Whitney test, the means of two dependent groups (baseline vs. follow-up) were compared using a Wilcoxon test and the percentage distribution of categorical variables was determined with a  $\chi^2$  test with Yates' correction when necessary.

The following three groups of respondents were considered: (i) with no increase in the nutrition knowledge score, (ii) with an increase in the nutrition knowledge score, (iii) with an increase in the nutrition knowledge score  $\geq 4$  points. To determine an association between nutrition knowledge and socioeconomic factors (gender, residence, FAS), logistic regression modelling was used to assess the chance of no increase in the nutrition knowledge score after a 3-month or 9-month follow-up in respect to the baseline. As a reference, two categories were considered, separately: (i) any increase in the nutrition knowledge score, (ii) an increase in the nutrition knowledge score  $\geq 4$  points; the modelled category was no increase. The odds ratios (ORs) and 95% CI were then calculated. A crude model and a model with an adjustment for gender, age (years), residence (urban, rural) and FAS (three categories: 0–4 points, 5–6 points, 7 points) were created, excluding the modelled variable from the confounders set, respectively. The significance of ORs was assessed by Wald's statistics. Statistica software package (version 12.0 PL, StatSoft Inc., Tulsa, OK, USA, StatSoft, Krakow, Poland) was used for all data analyses. Statistical significance ( $P$ ) was considered at three levels  $< 0.05$ ,  $< 0.01$ ,  $< 0.001$ .

## Results

**Changes in nutrition knowledge score three months after education.** In the educated group, the increase in the NKS in the total sample and all subgroups (girls, boys, rural residence, urban residence, low FAS, higher FAS) was found, on average by 2.0 to 3.2 points (Table 2 and Fig. 3). In the control group, the increase in the NKS averaged 0.6 to 0.7 points in all subgroups except for the low FAS subgroup ( $P = 0.08$ ). In the total sample and all subgroups, the increase in the NKS was significantly higher in the educated group than in the control group, on average by 1.4 to 2.7 points (all  $P < 0.001$ ).

**Changes in nutrition knowledge score nine months after education.** In the educated group, the increase in the NKS in the total sample and all subgroups (girls, boys, rural residence, urban residence, low FAS, higher FAS) was found, on average by 1.6 to 3.2 points (Table 2 and Fig. 3). In the control group, the increase in the NKS averaged 1.0 to 2.1 points in all subgroups. The increase in the NKS was significantly higher in the educated group than in the control group in rural residents (by 2.2 points,  $P < 0.001$ ) and in the total sample (by 0.4,  $P < 0.05$ ) while there was no significant difference in girls, boys, urban residents and teens with low or higher FAS.

**The chance of no increase in nutrition knowledge score three months after education.** In the educated group, the chance of no increase in the NKS was higher in urban residents than in rural residents, considering both any increase (adjusted OR 2.75,  $P < 0.01$ ) and an increase by  $\geq 4$  points (adjusted OR 3.63,  $P < 0.001$ ; Tables 3 and 4) as a reference. A similar association was found in the crude model. In the control group, the chance of no increase in the NKS was higher in the low FAS group (adjusted OR 2.67,  $P < 0.05$ ) than in the higher FAS group considering any increase as a reference.

**The chance of no increase in nutrition knowledge score nine months after education.** In the educated group, the chance of no increase in the NKS was higher in urban residents (adjusted OR 2.99,  $P < 0.001$ ) than in rural residents considering an increase by  $\geq 4$  points as a reference. A similar association was found in the crude model. In the control group, the chance of no increase in the NKS was lower in urban residents than in rural residents considering any increase (crude OR 0.46,  $P < 0.05$ ) and an increase by  $\geq 4$  points (crude OR 0.30,  $P < 0.01$ ) as a reference, however the association disappeared after adjustment for confounders.

Table 2  
Changes in nutritional knowledge score (points) three months and nine months after education by socioeconomic factors (mean and 95% confidence interval, 95% CI).

Variables	Baseline	After 3 months	After 9 months	Change after 3 months	P value	Change after 9 months	P value
Total sample							
educated	6.1 (5.9; 6.4)	8.5 (8.2; 8.8)	8.3 (7.9; 8.6)	2.4 (2.0; 2.7)	< 0.001	2.2 (1.7; 2.5)	< 0.001
control	5.5 (5.1; 6.0)	6.2 (5.7; 6.6)	7.2 (6.8; 7.6)	0.6 (0.3; 0.9)	< 0.001	1.7 (1.2; 2.1)	< 0.001
Difference	0.6	2.3	1.1	1.8		0.4	
P value	< 0.05	< 0.001	< 0.001	< 0.001		< 0.05	
Girls							
educated	6.6 (6.2; 7.0)	8.9 (8.5; 9.4)	8.6 (8.2; 9.1)	2.4 (1.9; 2.8)	< 0.001	2.0 (1.6; 2.5)	< 0.001
control	5.7 (5.0; 6.4)	6.3 (5.6; 7.0)	7.3 (6.7; 8.0)	0.6 (0.2; 1.0)	< 0.01	1.7 (1.0; 2.3)	< 0.001
Difference	0.9	2.6	1.3	1.8		0.6	
P value	< 0.05	< 0.001	< 0.01	< 0.001		0.15	
Boys							
educated	5.6 (5.1; 6.0)	7.9 (7.5; 8.4)	7.8 (7.3; 8.3)	2.3 (1.9; 2.8)	< 0.001	2.2 (1.6; 2.8)	< 0.001
control	5.4 (4.8; 6.0)	6.1 (5.4; 6.7)	7.1 (6.5; 7.7)	0.6 (0.1; 1.1)	< 0.05	1.6 (1.0; 2.3)	< 0.001
Difference	0.2	1.8	0.7	1.7		0.6	
P value	0.61	< 0.001	< 0.05	< 0.001		0.10	
Urban							
educated	6.3 (5.9; 6.6)	8.2 (7.8; 8.6)	7.9 (7.4; 8.3)	2.0 (1.6; 2.3)	< 0.001	1.6 (1.2; 2.0)	< 0.001
control	4.7 (4.2; 5.2)	5.3 (4.7; 5.8)	6.8 (6.3; 7.4)	0.6 (0.2; 0.9)	< 0.01	2.1 (1.5; 2.7)	< 0.001
Difference	1.6	2.9	1.1	1.4		-0.5	
P value	< 0.001	< 0.001	< 0.01	< 0.001		0.27	
Rural							
educated	5.9 (5.4; 6.4)	9.1 (8.6; 9.6)	9.1 (8.5; 9.6)	3.2 (2.6; 3.7)	< 0.001	3.2 (2.5; 3.9)	< 0.001
control	6.8 (6.0; 7.5)	7.4 (6.7; 8.2)	7.7 (7.0; 8.5)	0.7 (0.2; 1.3)	< 0.05	1.0 (0.3; 1.6)	< 0.01
Difference	-0.9	1.7	1.4	2.5		2.2	
P value	0.06	< 0.001	< 0.01	< 0.001		< 0.001	
Low FAS							
educated	5.7 (5.1; 6.2)	8.7 (8.1; 9.3)	8.4 (7.8; 9.0)	3.0 (2.4; 3.6)	< 0.001	2.7 (2.0; 3.5)	< 0.001
control	4.4 (3.6; 5.2)	4.8 (4.0; 5.5)	6.4 (5.6; 7.2)	0.3 (0.0; 0.7)	0.08	2.0 (1.0; 3.0)	< 0.001
Difference	1.3	3.9	2.0	2.7		0.7	
P value	< 0.05	< 0.001	< 0.001	< 0.001		0.11	
Higher FAS							
educated	6.3 (6.0; 6.7)	8.5 (8.1; 8.8)	8.2 (7.8; 8.6)	2.1 (1.8; 2.5)	< 0.001	1.9 (1.5; 2.3)	< 0.001
control	5.9 (5.4; 6.5)	6.7 (6.1; 7.2)	7.5 (7.0; 8.0)	0.7 (0.3; 1.1)	< 0.001	1.5 (1.0; 2.0)	< 0.001
Difference	0.4	1.8	0.7	1.4		0.4	
P value	0.16	< 0.001	< 0.05	< 0.001		0.10	
Nutrition knowledge score (range: 0–18).							

FAS indicates Family Affluence Scale (low: 0–4 points, higher: 5–7 points).

Difference calculated as the absolute difference between the educated vs. control group.

Change calculated as the difference between follow-up vs. baseline within one group (educated or control).

*P*value – significance level for difference (Mann-Whitney test) or change (Wilcoxon test).

Table 3

Sample distribution (%) by the change in nutrition knowledge score and socioeconomic factors three months and nine months

After 3 months										After 9 months									
Variables	No increase				Any increase				Increase ≥ 4 points				No increase				Any increa		
	Total	Edu	Con	P	Total	Edu	Con	P	Total	Edu	Con	P	Total	Edu	Con	P	Total	E	
Sample size	166	80	86		296	239	57		119	109	10		156	93	63		306	2	
Sample percentage	100.0	48.2	51.8		100.0	80.7	19.3		100.0	91.6	8.4		100.0	59.6	40.4		100.0	7	
Gender	0.42				0.16				0.17				0.36						
Girls	53.6	57.5	50.0		53.0	55.2	43.9		55.5	57.8	30.0		51.3	54.8	46.0		54.6	5	
Boys	46.4	42.5	50.0		47.0	44.8	56.1		44.5	42.2	70.0		48.7	45.2	54.0		45.4	4	
Residence	< 0.01				0.56				0.49				< 0.001						
Urban	70.5	82.5	59.3		62.2	63.2	57.9		55.5	56.9	40.0		64.1	75.3	47.6		65.4	6	
Rural	29.5	17.5	40.7		37.8	36.8	42.1		44.5	43.1	60.0		35.9	24.7	52.4		34.6	3	
FAS																			
Low	24.1	17.5	30.2		22.0	23.4	16.1		24.4	25.7	10.0		18.1	15.2	22.2		24.1	2	
Higher	75.9	82.5	69.8	0.08	78.0	76.6	83.9	0.31	75.6	74.3	90.0	0.47	81.9	84.8	77.8	0.37	75.9	7	
Nutrition knowledge score (range: 0–18).																			

FAS indicates Family Affluence Scale (low: 0–4 points, higher: 5–7 points).

Edu indicates – educated group, Con – control group.

*P*value – significance level of  $\chi^2$  test with Yates' correction.

Table 4  
Odds ratios (95 % Confidence Intervals) for no increase in nutrition knowledge score three months and nine months after education by socioeconomic factors.

Variables	Models	After 3 months		After 9 months	
		No increase	No increase	No increase	No increase
		(ref.: any increase)	(ref.: increase by ≥ 4 points)	(ref.: any increase)	(ref.: increase by ≥ 4 points)
Girls (ref.: boys)					
educated	Crude	1.10	0.99	0.95	1.12
		(0.66, 1.83)	(0.55, 1.78)	(0.58, 1.54)	(0.63, 1.99)
	Adjusted	1.05	0.85	0.92	1.02
		(0.62, 1.77)	(0.46, 1.59)	(0.56, 1.51)	(0.56, 1.87)
control	Crude	1.28	2.33	0.85	1.34
		(0.65, 2.52)	(0.56, 9.80)	(0.35, 2.05)	(0.58, 3.12)
	Adjusted	1.29	2.36	0.85	1.31
		(0.64, 2.58)	(0.52, 10.59)	(0.43, 1.69)	(0.54, 3.19)
Urban (ref.: rural)					
educated	Crude	2.75**	3.57***	1.64	3.04***
		(1.45, 5.19)	(1.78, 7.16)	(0.95, 2.83)	(1.64, 5.65)
	Adjusted	2.75**	3.63***	1.66	2.99***
		(1.45, 5.20)	(1.80, 7.31)	(0.96, 2.89)	(1.60, 5.59)
control	Crude	1.06	2.19	0.46*	0.30**
		(0.53, 2.10)	(0.56, 8.46)	(0.23, 0.92)	(0.12, 0.76)
	Adjusted	0.77	1.03	0.48	0.38
		(0.35, 1.66)	(0.19, 5.57)	(0.23, 1.01)	(0.14, 1.05)
Low FAS (ref.: higher)					
educated	Crude	0.69	0.61	0.62	0.59
		(0.36, 1.33)	(0.30, 1.27)	(0.33, 1.20)	(0.28, 1.23)
	Adjusted	0.74	0.67	0.66	0.67
		(0.38, 1.43)	(0.32, 1.42)	(0.34, 1.27)	(0.31, 1.46)
control	Crude	2.26	3.90	0.70	0.48
		(0.96, 5.33)	(0.46, 33.30)	(0.32, 1.51)	(0.19, 1.21)
	Adjusted	2.67*	3.73	0.83	0.68
		(1.08, 6.63)	(0.39, 35.25)	(0.37, 1.86)	(0.25, 1.86)
Sample size may vary in variables due to missing data.					

FAS indicates Family Affluence Scale (low: 0–4 points, higher: 5–7 points).

Adjusted model: odds ratios adjusted for confounders (at follow-up): gender (girls, boys), age (years), residence (urban, rural), FAS (three categories: 0–4 points, 5–6 points, 7 points), excluding the modelled variable from the confounders' set, respectively.

Statistically significant (Wald's statistics): \**P* value < 0.05, \*\**P* < 0.01, \*\*\**P* < 0.001.

## Discussion



Considering the total sample, multi-component education improved the nutrition knowledge of teenagers both three and nine months after education. This effect was visible after three months, regardless of sex, place of residence or family affluence, but weakened after nine months, with the exception of rural residents.

The study showed that the implemented multi-component education related to healthy eating, physical activity, culinary experiments and food safety in the long-term has improved the nutrition knowledge of teenagers. Considering the total sample, the education program turned out to be effective after both three and nine months. A significant increase in the nutrition knowledge score was noted – in the educated group on average by 2.4 and 2.2 points after three and nine months, respectively. The nutrition knowledge score was also increased in the control group but the average increase was significantly greater in the educated group than in the control group (by 1.8 and 0.4 points for difference after 3 and 9 months, respectively). The increase in nutrition knowledge in the control group may be attributed to regular school education and out-of-school influences while in the educated group it was undoubtedly the result of the implemented education program together with school and out-of-school influences. Some previous studies have also evaluated the effectiveness of multi-component intervention models of nutritional and lifestyle education, but the follow-up period from these interventions was shorter and ranged from three to six months [38, 39, 40]. Only Zhou et al. [41] studied the effectiveness of pre-/post-intervention within a nine-month follow-up. In contrast to the current study, knowledge scores in the intervention group were significantly lower after the three- and nine-month follow-up than immediately after the intervention [41].

The studies mentioned above included multi-component intervention packages and were addressed to children and adolescents (Iranian 12–16 years old; Indian 8–18 years old; Chinese 11–14 years old) and their parents and teachers [38, 39, 40, 41], so were differently designed in comparison with the current study. In the present study, the education program was related to 11-12-year old teenagers and was not supported by parents or teachers during education and follow-up. Due to the positive result of the current education program in a nine-month follow-up and the failure of the program by Zhou et al. [41], the current results confirm that the proposed model of education addressed only to 11-12-year old teens was effective and can be widely recommended.

When considering the residence, the results clearly showed that the increase in nutrition knowledge score was much higher among students living in rural areas than those living in urban areas. For rural teens, these differences remained statistically significant also after nine months from the intervention, being similar to those after three months (average difference was 2.2 and 2.5 points, respectively). Moreover, the chance of the lack of an educational effect, taking into account confounders and regardless of the referent category, was approx. three times greater in urban teens than in rural teens. The positive effect of educational intervention on nutrition knowledge or practice has been shown by several studies of rural residents [17, 42, 43, 44]. However, the mentioned studies covered only the rural teen populations, thus the effectiveness of nutrition education refers only to them. The current study was more broadly designed and compared the same model of education in different places of residence to assess whether it is a factor influencing the outcome of nutrition knowledge. The findings from the current study are in line with a cross-sectional study carried out in the federal state of Tyrol in western Austria [45] which found associations of higher nutrition knowledge in Austrian students from rural schools and better use of weekly nutrition education classes in comparison to students from urban schools. It may be speculated that the urban environment provides young people with more stimuli and creates various opportunities to modulate their knowledge, both increasing or decreasing it. Frequent contact with many people, both direct or via social media and the appearance of much news in the public spaces may weaken previously gained knowledge that has not been consolidated or change it based on false evidence. So-called 'fake' news related to diet and health is especially frequently distributed via social media and the Internet through idols and influencers [46, 47, 48]. Such news may be uncritically and easily adopted by a young audience who do not have the competence to verify it with scientific evidence. Therefore, it is possible to conclude from the current research, supported by previous results, that rural teens are more sensitive to multi-component nutrition education while special attention should be paid to urban teens. To achieve a long-lasting educational effect in urban teens, additional activities supporting the previously gained knowledge should be considered. In the authors' opinion, nutrition education programs should be designed to provide additional simple, supportive education a few months after basic education has been completed.

As far sex subgroups are concerned, the educational effect was similar in girls and boys. The average difference in the increase in nutrition knowledge score, three months after education was higher in girls/boys who attended the education program than in those out of the program however nine months after education this significance disappeared both in girls and boys. Moreover, the chance of the lack of an educational effect, taking into account confounders and regardless of the referent category, was similar in girls and boys. This finding is in line with a study by Lai Yeung [49]. The author found that 11-16-year old boys and girls from Hong Kong showed a similar level of nutrition knowledge and, moreover, a similar consumption of vegetables, fruit, milk and bread. In contrast to the current findings and Lai Yeung [49], most studies have found that girls have healthier eating habits and higher nutrition knowledge than boys [50, 51, 52, 53]. Cross-cultural studies indicate that women focus on healthy eating choices, e.g. avoiding fat-rich foods and salt as well as consuming more fruits and fibre, for better weight control [51, 54]. Lipowska et al. [52] suggest that even five-year-old girls are probably aware of the social importance of diet and, thus, internalize healthier eating habits. Altogether, this indicates that while gender plays a significant role in food choices and preferences, the education related to knowledge of nutrition and lifestyle is similarly effective in girls and boys.

Regarding family affluence, the educational effect was similar in teenagers with low and higher family affluence. As was described above with respect to sex, among teenagers with low and higher family affluence, a similar improvement in nutrition knowledge score three months after education was found with no significant improvement after nine months. Furthermore, the chance of the lack of an educational effect was similar in both teenager groups (with low and higher family affluence). This finding suggests that family affluence is not a factor shaping long-term maintenance of the nutrition knowledge among Polish teenagers and this factor can be excluded from the confounders set when designing educational programs. It is difficult to compare the current findings with others because the present study was designed as an intervention with a control group in which the change in nutrition knowledge was a study outcome. Some studies involving adolescents from Europe, Canada and Israel included dietary habits as a study outcome and showed a high level of inequality in daily food consumption related to family wealth [55, 56]. However, due to the cross-sectional design of those studies, the changes in nutrition knowledge related to family affluence cannot be interpreted. Further studies of teenagers from other European countries should be carried out to confirm (or not) that family affluence has no impact on improving and long-term maintenance of teenagers' nutrition knowledge.

**Strengths and Limitations.** The main advantage of this study was the relatively large sample size (464 teenagers) subjected to 9-month follow-up. A very rigorous selection of the sample was applied, each participant had to take part in lectures and workshops within all five topics of the education program lasting three weeks; students who missed even one lecture or workshop were excluded. Data collection and all measurements were taken by well-trained researchers with the same type of equipment in all scientific centres to minimize inter-centre differences. Data related to nutrition knowledge and socioeconomic variables were collected with a food frequency questionnaire (SF-FFQ4PolishChildren) which has a known quality and can be recommended to evaluate dietary and lifestyle behaviours among children and adolescents [35].

The main limitation is a lack of random allocation of subjects to the educated and control groups. Unfortunately, the authors were unable to apply the random approach for several reasons. First, for organizational reasons, the authors wanted to choose schools located at a convenient distance from the academic centres (up to 50 km). Second, many school principals (surprisingly) did not permit their school to participate in the study. Third, many of the schools had previously participated in other nutrition- or health-related education programs, so they could not be included in our study. There was an element of randomness in the current study since assigning classes to the educated or control group was accidental.

## Conclusions

The results suggest that in general, the 'ABC of Healthy Eating' program is a good model for improving teenagers' nutrition knowledge. Taking into consideration the socio-economic context, the 'ABC of Healthy Eating' program improved the nutrition knowledge of teenagers in the short-term regardless of sex, residence or family affluence but in the long-term, this effect was visible only in rural residents. This suggests that rural teens are more sensitive to multi-component nutrition education while special attention should be paid to urban teens if nutrition education is being developed and implemented. Future studies should focus on comprehensive understanding of barriers attenuating long-term effectiveness of multi-component, nutrition education in urban teenage residents and, next, developing and testing a special path of nutrition education addressed to urban teens. A simple temporary solution is proposed to design nutrition education programs containing additional simple, supportive education a few months after basic education has been completed. Such a design should strengthen the effects of nutrition education and boost its long-term maintenance in urban teens and bring additional benefits to other socioeconomic groups of teenagers.

## Declarations

### Acknowledgements

Thanks are expressed to the participants for their contributions to the study and the academic researchers from: Warsaw University of Life Sciences (WULS-SGGW), Gdynia Maritime University, Faculty of Health Sciences, University of Agriculture in Krakow, University of Life Sciences in Lublin, University of Life Sciences in Poznan, University of Warmia and Mazury in Olsztyn, Wrocław University of Environmental and Life Sciences.

### Authors' contributions

J.H., L.W. and J.K. were responsible for the conception and design of the main study and this paper. J.H. was involved in the funding acquisition in respect to the project and managing of the project. J.K. was responsible for the data cleaning and statistical analysis for the main study and this paper. L.W., M.K. and J.K. were responsible for data interpretation for this paper. M.K., J.K., M.J.-B., M.T., A.D. and J.H. were responsible for data collection of the main study. L.W. and M.K. were responsible for data visualization. L.W. and M.K. were responsible for writing the original draft of the manuscript. J.H. was responsible for revising the manuscript critically for important intellectual content.

### Funding

Funding for this study was provided by Carrefour Foundation (Agreement ABC No.1/2014) and each scientific centre from sources of the Polish Ministry of Sciences and Higher Education.

### Availability of data and materials

Supplementary data related to the article can be found at.....

### Ethics approval and consent to participants

The project followed the ethical standards recognized by the Declaration of Helsinki and was approved by the Bioethics Committee of the Faculty of Medical Sciences, University of Warmia and Mazury in Olsztyn on 17 June 2010, Resolution No. 20/2010. The study was explained to the participants before the start (verbally and by leaflets), pupils at school lessons and parents or legal guardians during meetings. Parental or legal guardians' written informed consent was obtained for the participation of their children.

### Consent for publication

not applicable

### Competing interest

None declared. The sponsoring agencies had no role in the study design, data collection, analysis or interpretation of the data, the writing of the manuscript or the decision to publish the results.

## Abbreviations

ABC-HEat – ABC of Healthy Eating program;

SF-FFQ – short form of a food frequency questionnaire;

FAS – family affluence scale;

NKS – nutrition knowledge score;

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## Figures

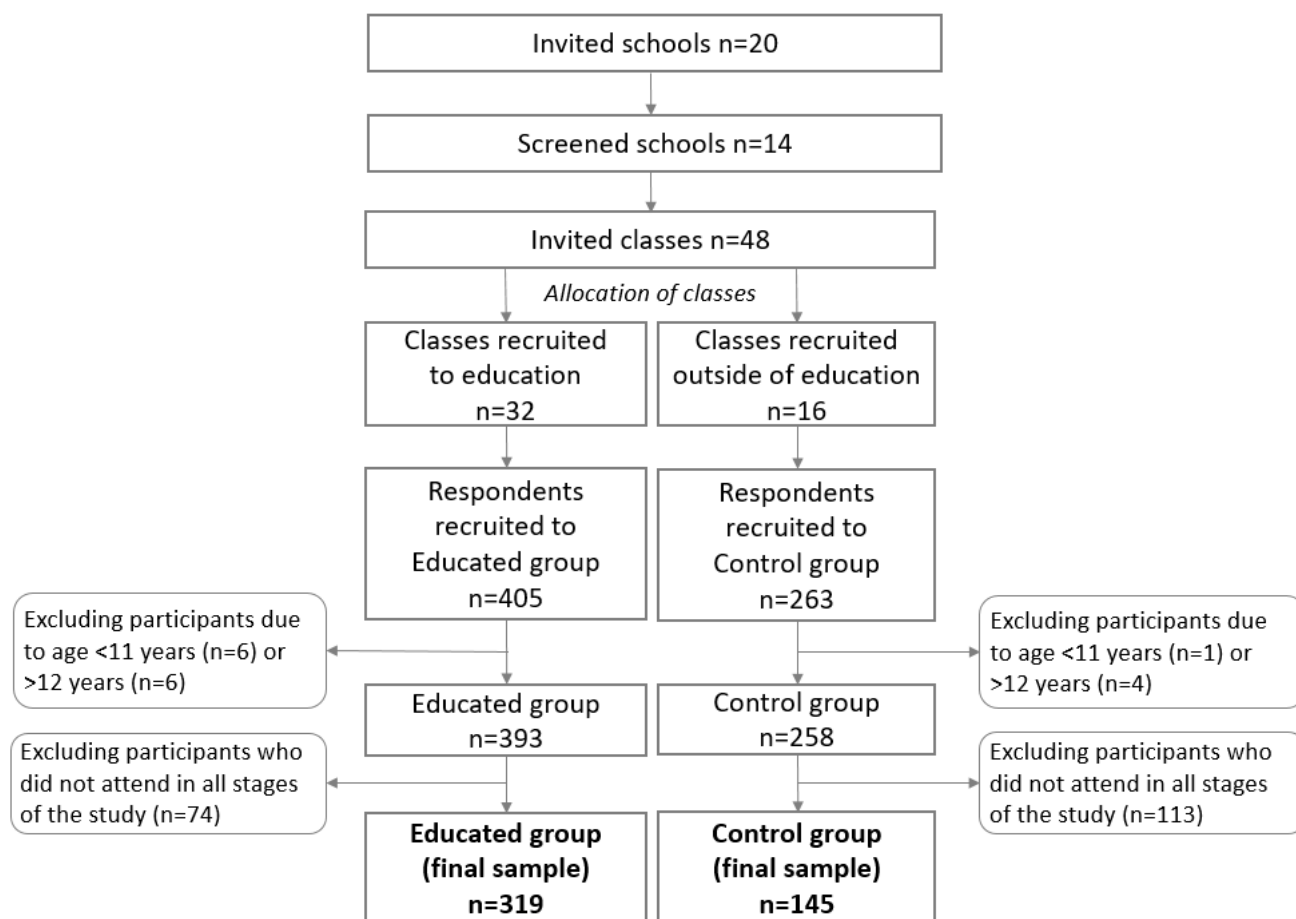


Figure 1

Flow chart of sample collection and study design.

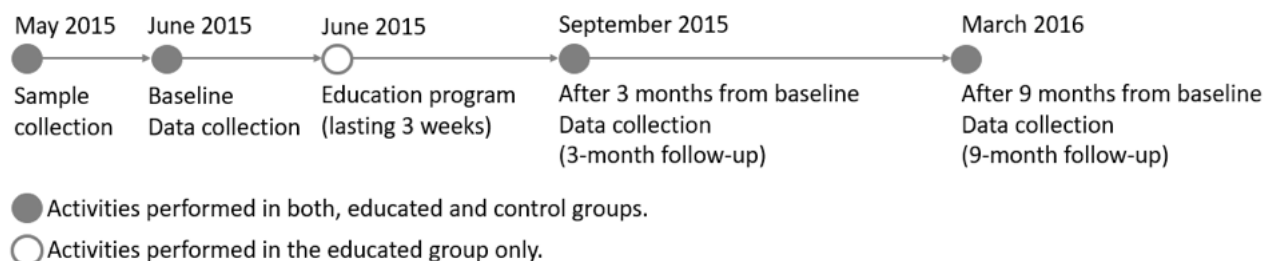
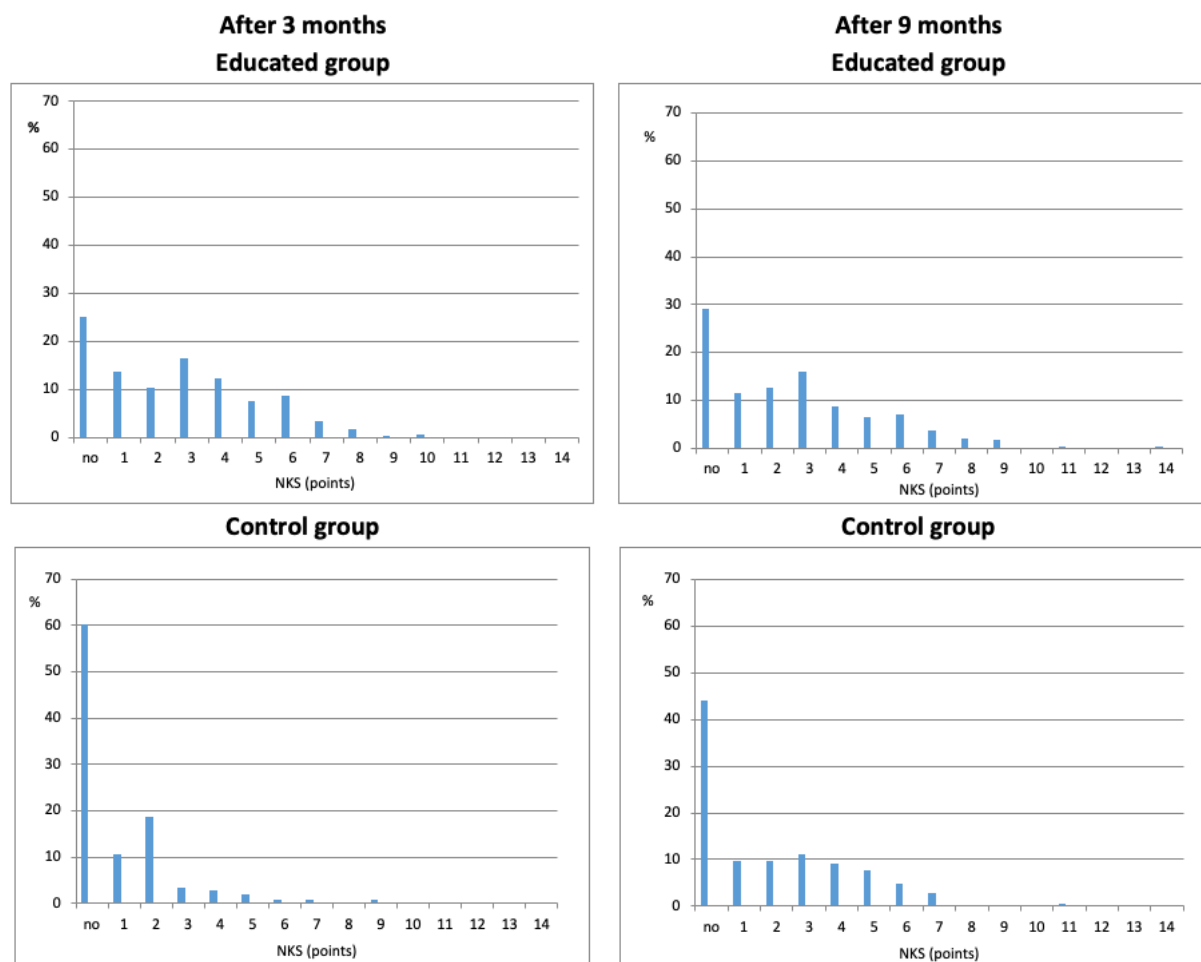


Figure 2

Timeline and activities of the ABC-HEat program.



**Figure 3**

Sample distribution (%) by changes in nutrition knowledge score (NKS) after three months and nine months. Notes: no – means no increase in NKS

## Supplementary Files

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