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Original article

Diet quality at age 5–6 and cardiovascular outcomes in preadolescents

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SUMMARY

Background & aims: Specific dietary components during childhood may affect risk factors for cardiovascular disease. Whether overall higher diet quality prevents children from adverse cardiovascular outcomes remains contradictive. We aimed to examine the associations between diet quality at age 5–6 years and cardiovascular outcomes after a 6-year follow-up.
Methods: We used data from the Amsterdam Born Children and their Development study, a multi-ethnic birth cohort. Dietary intake was assessed at age 5–6 using a semi-quantitative food frequency questionnaire and diet quality was ascertained with the Dietary Approaches to Stop Hypertension (DASH) score and the child diet quality score (CDQS), an index specifically developed for Dutch school-age children. Cardiovascular outcomes were examined after 6-years follow-up (age 11–12, N = 869). Outcomes were body mass index (BMI), waist circumference (WC), blood pressure (BP), lipid profile, fasting glucose and carotid intima-media thickness (CIMT). Multivariable linear and logistic regression models adjusted for baseline value were used to examine associations between diet quality and cardiovascular outcomes.
Results: Higher diet quality at age 5–6 was associated with lower BMI (DASH score: Δ quintile (Q) 5 and Q1: −0.35 kg/m^2, p for trend = 0.016), lower WC (DASH score: Δ Q5 and Q1: −1.0 cm, p for trend = 0.028), lower systolic (DASH score: Δ Q5 and Q1: −2.7 mmHg, p for trend = 0.046) and diastolic BP (DASH score: Δ Q5 and Q1: −2.4, p for trend < 0.001) and with lower plasma triglycerides (DASH score: Δ Q5 and Q1: −0.20 mmol/L, p for trend = 0.032) after 6-years follow-up. Associations of the CDQS with these outcomes showed similar trends, but less pronounced. We found no statistically significant associations between diet quality and LDL-C, HDL-C, total cholesterol, fasting glucose or CIMT.
Conclusions: Higher diet quality in childhood at age 5–6 years predicted better health on some cardiovascular outcomes in preadolescence.

1. Introduction

In recent decades, cardiovascular diseases (CVD) became a leading cause of health loss and premature death worldwide [1]. Atherosclerosis, a complex process in patients' arteries, already begins at a young age and is considered the root cause of CVD [2,3]. Among the contributing factors for developing atherosclerosis are hypertension, obesity and high levels of cholesterol and glucose, which in turn are influenced by lifestyle, including diet [2,4].

Few data exist on the relation between diet during childhood and incidence of CVD in adulthood. Nevertheless, childhood

Abbreviations: ABCD, Amsterdam Born Children and their Development; FFQ, food frequency questionnaire; CDQS, Child Diet Quality Score; DASH, Dietary Approaches to Stop Hypertension; CIMT, carotid intima-media thickness.

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nutrition seems to be an important target to prevent CVD and risk factors for CVD that predict CVD risk later in life can already be measured in childhood [4,5]. In children and adolescents, several individual foods, like dairy products and sugar-sweetened beverages, have been associated with CVD risk factors in cross-sectional studies [6,7]. However, because diets consist of multiple different components rather than isolated foods, nutritional epidemiology has focused more on assessing dietary patterns. One method to define dietary patterns is using dietary quality indices, which determine the degree of adherence to, for example, specific dietary guidelines or the Mediterranean Diet. Such ‘a priori’-derived dietary pattern approaches make it possible to evaluate whether adherence to a particular diet reduces the risk of certain diseases, like CVD [8,9].

Current evidence on associations between diet quality and cardiovascular risk in children is less clear than in adults. Cross-sectional research showed lower overall cardiometabolic risk in boys with higher Finnish Children Healthy Eating Index scores at age 6–8 [10]. However, this was not found in girls, nor in relation with the DASH score, Baltic Sea Diet Score or Mediterranean Diet Score [10]. A longitudinal study concluded that better compliance to Australian dietary guidelines at age 14 was associated with higher body mass index (BMI), but with lower waist-hip ratio and lower triglycerides and not associated with blood pressure (BP) or other blood lipids at age 17 years [11].

The DASH score has frequently been used in studying the association between diet quality and risk factors for CVD in childhood [10,12–17]. These studies tend to confirm an association between higher DASH score and lower BP. However, they are mostly conducted cross-sectionally, in a variety of age groups and associations with other cardiovascular outcomes are inconsistent. Recently, a food-based child diet quality score (CDQS) based on dietary guidelines for school-age children in the Netherlands was developed [18]. This score has been used to examine the relationship between diet quality and body composition in childhood and found a positive association between diet quality and BMI over time [19]. Associations between the CDQS and other cardiovascular risk factors in children have not yet been studied.

The objective of the present study was to examine associations between diet quality, operationalised as the DASH score and CDQS, at age 5–6 and cardiovascular risk factors at age 11–12 in a sample of Dutch children.

2. Materials and methods

2.1. Study design and population

We used data from the Amsterdam Born Children and their Development (ABCD) study, a prospective cohort study with the aim to examine the associations of early life circumstances with health at birth and later in life. A detailed description of the study has been published previously [20]. In brief, between January 2003 and March 2004, all pregnant women in Amsterdam attending their first pregnancy check-up were invited for participation in the study. Of the in total 12,373 addressed women, 8266 completed a pregnancy questionnaire. Mothers of singleton infants, who granted permission for follow-up, were invited for the 5-year measurement (N = 6161). For this measurement, a questionnaire and an invitation for a health check, comprising various physical assessments, were sent [21]. A self-administered food frequency questionnaire (FFQ) was received by the mothers who gave permission for the health check and returned by 2851 of them. After excluding the children with more than 50% missing information per food component or per page of the FFQ, FFQ data for 2782 children were applicable for analysis. Of this group, a sample of 2724 had data on at least one cardiovascular risk factor (BMI, waist circumference (WC), blood pressure (BP), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), total cholesterol, triglycerides, or fasting glucose). At the age of 11–12, in a randomly selected subgroup again a questionnaire was sent and a health check was performed. Carotid intima-media thickness (CIMT) measurement had been added to the health check by that time. 1082 children participated in the cardiovascular measurements. A set of 873 children had complete FFQ data and data on at least one cardiovascular outcome at age 11–12. We excluded children with congenital CVD and those who used drugs intervening with cardiovascular risk factors (antihypertensive or anti-hypotensive drugs, vasoprotective drugs, insulin or statins) from all analyses. A flowchart of the methodology is presented in Supplementary Fig. 1.

The Central Committee on Research Involving Human Subjects in the Netherlands, the medical ethics review committees of the participating hospitals and the Registration of the Municipality of Amsterdam approved the protocol of the ABCD study and written informed consent of all the participants was obtained.

2.2. Participant characteristics

Baseline characteristics were obtained from questionnaires and the health check at age 5–6. Total energy intake per day and total scores of the dietary quality indices were calculated based on the data from the FFQ. Details about duration of physical activity (including walking and cycling to school, playing outside and exercise at sports clubs) and electronic screen time (watching television and playing computer games) were obtained from the questionnaire at age 5–6 [22]. This questionnaire also provided information on maternal educational level (low, primary school or lower general secondary education; middle, higher general secondary education; high, graduate school or university), BMI of the parents (self-reported) and the presence of cardiovascular risk factors and CVD among close relatives. Ethnicity (Dutch, Surinamese, Turkish, Moroccan, other Western or other Non-Western) was derived from the pregnancy questionnaire. The questionnaire at age 11–12 also yielded information on physical activity, screen time and sexual maturation by means of the Puberty Development Scale [23].

2.3. Assessment of dietary intake

A 71-item semi-quantitative FFQ developed by TNO Food & Nutrition (Zeist, the Netherlands) was administered by the parents to assess the children's habitual dietary intake. This FFQ had been validated against doubly labelled water and was ascertained to be an accurate instrument for determining energy intake in children aged 4–6 years old in the Netherlands [24]. Information on consumption frequency (ranging from never to six/seven days per week), quantity (natural units, household units or grams) and precise food type was converted into the amount consumed per individual food item in grams per day using the Dutch Food Composition Database 2010 (RIVM, Bilthoven, the Netherlands) [25].

2.4. DASH score

The DASH score used in this study was based on the score developed by Fung et al. and addressed the following components: fruits, vegetables, nuts and legumes, whole grains, low-fat dairy, red and processed meat and sweetened beverages [26]. Since the FFQ used in the ABCD cohort is not appropriate for salt intake determination, we omitted this component. Supplementary Table 1 shows the food items of our FFQ that were sorted into the different components. The applied DASH score uses a ranking system in quintiles where quintile one represents participants with the lowest intake of a certain component and is awarded one point, quintile two, two points, and so on. The components red and processed meat and sweetened beverages, for which a lower intake is advised, are scored in reverse. The total DASH score is a sum of scores of all individual components (range 7–35) and was calculated for all children with a complete FFQ and at least one cardiovascular outcome at age 5–6.

2.5. CDQS

The CDQS developed by Nguyen et al. was specifically established for school-age children in the Netherlands and based on Dutch dietary guidelines [18,27]. The score consists of ten components, each yielding a maximum score of 1 when the dietary recommendation is met. The included recommendations are: fruits ≥150 g/day, vegetables ≥125 g/day, whole grains ≥90 g/day, fish ≥55 g/week, legumes ≥84 g/week, nuts ≥15 g/day, dairy ≥300 g/day, oils and soft or liquid fats ≥30 g/day, sugar-containing beverages ≤150 g/day and processed meat ≤250 g/week. When the recommendation is not met, the score is calculated proportionally. For example, when only a quarter of the advised amount is consumed, the score is 0.25 for that particular component. For sugar-containing beverages and processed meat the score is reversed. The total CDQS was a sum of the scores of individual components, with a theoretical range from 0 to 10 on a continuous scale.

2.6. Assessment of cardiovascular outcomes

Assessed cardiovascular outcomes were BMI, WC, systolic and diastolic BP, LDL-C, HDL-C, total cholesterol, triglycerides, fasting glucose and CIMT. Anthropometric measurements at both ages were performed in the same manner [28]. A portable Leicester stadiometer (Seca, Hamburg, Germany) and a Marsden weighing scale (Model MS-4102, Rotherham, United Kingdom) were used to measure height and weight, respectively. WC was determined with non-elastic measuring tape (Seca, Hamburg, Germany) at the midpoint between the lower costal margin and the iliac crest. BP was determined in lying position using the Omron 705 IT (Omron Healthcare Inc., Bannockburn, IL, USA) with a small cuff [29]. It was measured twice and after five minutes of rest. When a difference >10 mm Hg between the two measurements occurred, a third assessment was applied. The mean of the two systolic BP measurements and the two diastolic BP measurements that were closest to each other was used in the analyses [28].

Capillary blood samples were drawn by a finger-prick after an overnight fast in children aged 5–6 using a validated collection kit (Demecal, Lab Anywhere, Haarlem, the Netherlands) [30]. In the 11–12 year old children, blood sample collection was performed after three hours of fasting, also with a finger-prick and analysed by the Alere Cholestech LDX Analyzer (Alere Inc, Abbott, Chicago, IL, USA). Blood samples at both ages were analysed on concentrations of LDL-C, HDL-C, total cholesterol, triglycerides and fasting glucose.

At age 11–12, the CardioHealth Station V1.8 (Panasonic, Osaka, Japan) was used to perform real-time automated CIMT measurements. The CIMT is a validated surrogate marker for CVD and essentially a measure of atherosclerosis in adults and atherosclerotic changes in children and thereby a powerful indicator for future cardiovascular outcomes [31,32]. With the child's head in an angle of 45° and in supine position, CIMT was bilaterally measured in three different angles. Mean CIMT was used in our analyses and calculated with measurements of at least three angles.

In addition to continuous cardiovascular risk factors, we also analysed associations of diet with presence of overweight, prehypertension, dyslipidaemia, high risk CIMT and metabolic syndrome as dichotomous variables. Overweight was defined as BMI > +1 age and sex standardized SDS using WHO reference curves [33]. We considered prehypertension as systolic and/or diastolic BP levels ≥90th percentile of our study population [34]. Criteria for dyslipidaemia were set at total cholesterol >5.2 mmol/L, or LDL-C > 3.4 mmol/L, or HDL-C < 0.9 mmol/L, or triglycerides >1.7 mmol/L, or a combination of them [35]. CIMT measurements ≥90th percentile were considered high risk [36]. Children were regarded as having metabolic syndrome when having three or more of the following criteria: WC ≥ 75th percentile, systolic or diastolic BP ≥ 75th percentile, HDL-C ≤ 25th percentile, triglycerides ≥75th percentile or fasting glucose ≥75th percentile [37].

2.7. Statistical analysis

We performed all analyses using IBM SPSS Statistics software (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). *P*-values < 0.05 were considered statistically significant. To be able to compare the two dietary quality indices, we divided total scores of both indices in quintiles. Baseline characteristics of the study population were described according to the diet quality distribution at age 5–6. To study the association between diet quality at age 5–6 and risk factors for CVD at age 11–12, we used multivariable linear and logistic regression models for continuous and categorical outcomes, respectively. Covariates in our regression models were gender, educational level of the mother, total energy intake and baseline value of the studied risk factor (measured at age 5–6) and age, physical activity, screen time and sexual maturation (measured at age 11–12) [38–40]. Analyses on the association between diet quality and CIMT were not adjusted for baseline value (as this measure was not available), but additionally adjusted for person assessing the CIMT. Considering diet quality in quintiles as a continuous variable, *p*-value for trend was calculated for all regression analyses. We conducted two sensitivity analyses; because total energy intake and maternal educational level are factors likely playing a role in diet quality, we re-run our analyses without adjustments for these variables to study their impact [39,41].

3. Results

3.1. Baseline characteristics

Baseline characteristics of the study sample stratified by quintiles of the DASH score are displayed in Table 1. A total of 869 children was included with a mean age of 5.1 years (SD ± 0.2). Boys and girls were approximately equally distributed, with 52.0% boys in the whole sample. The majority of children had mothers of Dutch origin (75.9%). Mean DASH score was 21.1 (SD ± 4.2) and children with higher DASH scores had higher energy intakes per day. Moreover, children with higher DASH scores were more physically active, spent less time using screens and more often had parents with a normal body weight. Children with low educated mothers or an ethnic minority background were proportionally more represented in the lowest quintile of the DASH score. Higher DASH score was also associated with higher BMI and larger WC and with lower scores on other cardiovascular outcomes at baseline, although differences were rather small. Similar distributions of participant characteristics were observed per quintiles of the CDQS, presented in Supplementary Table 2.

3.2. Diet quality

Diet quality at the age of 5–6 years based on the DASH score ranged from 8 to 34 (maximum 35). Total CDQS at this age varied between 0.86 and 9.07 (maximum 10). Mean intake (g/day) per DASH component and per quintile of the DASH component is demonstrated in Supplementary Table 3. Total DASH scores and CDQS were highly correlated (Pearson's r = 0.7, $p < 0.001$). The mean score on the Puberty Development Scale was 1.52 (SD ± 0.54).

3.3. Linear regression analyses

We observed several associations between diet quality at age 5–6 and cardiovascular outcomes at age 11–12 (Table 2). After adjustments, higher DASH scores were associated with lower BMI (p for trend = 0.016), smaller WC (p for trend = 0.028), lower systolic (p for trend = 0.046) and diastolic BP (p for trend < 0.001) and lower plasma concentrations of triglycerides (p for trend = 0.032). Higher CDQS was associated with lower BMI (p for trend = 0.036) and lower triglycerides (p for trend = 0.044). There were no associations between diet quality at age 5–6 and LDL-C, HDL-C, total cholesterol, fasting glucose or CIMT at age 11–12, using any of the two dietary quality indices.

Our sensitivity analyses demonstrated that excluding adjustments for total energy intake and maternal educational level changed the associations to some extent. Excluding total energy intake from the model meant that the associations between diet and triglycerides were no longer statistically significant, with p-values for trend being 0.069 and 0.096, for DASH and CDQS respectively. Furthermore, after omitting total energy intake, higher CDQS was negatively associated with WC (p for trend = 0.033) and diastolic BP (p for trend = 0.042). No adjustment for maternal educational level did not change the associations found with the DASH score. However, negative associations became apparent between CDQS and WC (p for trend = 0.013), diastolic BP (p for trend = 0.031) and CIMT (p for trend = 0.043).

3.4. Logistic regression analyses

Multivariable logistic regression showed an association between the DASH score at age 5–6 and risk of prehypertension and dyslipidaemia at age 11–12 (Table 3). One quintile increase of the DASH score was associated with lower risk of prehypertension (aOR: 0.77; 95% CI: 0.64–0.93, $p = 0.006$) and dyslipidaemia (aOR: 0.79; 95% CI: 0.65–0.95, $p = 0.012$). The CDQS was also associated with risk of dyslipidaemia 0.79 (95% CI: 0.66–0.95, $p = 0.014$), but not with prehypertension. We found no associations between diet quality at age 5–6 and risk of overweight, high risk CIMT or metabolic syndrome in preadolescents. Figure 1 shows the predicted probability of prehypertension and dyslipidaemia at age 11–12 as a function of the DASH score.

Table 1
Baseline characteristics of children and parents according to children's DASH score at age 5–6 years.

	DASH score			
	All	Q1	Q2-4	Q5
N	869	174	559	136
Age (y)	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.1
Boy (%)	52.0	52.9	52.2	50.0
DASH score	21.1 ± 4.2	15.1 ± 1.9	21.4 ± 2.2	27.5 ± 1.5
Total energy intake (kcal/d)	1520.9 ± 318.0	1411.3 ± 282.0	1532.3 ± 324.2	1614.1 ± 298.7
Energy intake per kg body weight (kcal/kg/d)	73.6 ± 17.1	68.7 ± 16.4	74.1 ± 17.3	77.7 ± 16.0
Height (cm)	116.5 ± 5.7	116.5 ± 5.3	116.6 ± 6.0	116.5 ± 5.2
BMI (kg/m^2)	15.39 ± 1.30	15.36 ± 1.47	15.37 ± 1.24	15.48 ± 1.30
Overweight (%)[a]	12.0	10.9	12.0	13.2
WC (cm)	52.3 ± 3.4	52.1 ± 3.7	52.2 ± 3.4	52.6 ± 3.0
Systolic BP (mm Hg)	98.9 ± 7.0	99.7 ± 7.9	98.8 ± 6.6	98.3 ± 7.0
Diastolic BP (mm Hg)	56.7 ± 6.0	57.1 ± 6.7	56.7 ± 5.6	56.6 ± 6.6
LDL-C (mmol/L)	2.34 ± 0.68	2.34 ± 0.67	2.36 ± 0.72	2.29 ± 0.53
HDL-C (mmol/L)	1.30 ± 0.30	1.35 ± 0.28	1.29 ± 0.31	1.29 ± 0.30
Total cholesterol (mmol/L)	4.05 ± 0.71	4.07 ± 0.70	4.04 ± 0.74	4.02 ± 0.57
Triglycerides (mmol/L)	0.65 ± 0.31	0.61 ± 0.29	0.66 ± 0.32	0.64 ± 0.27
Fasting glucose (mmol/L)	4.59 ± 0.51	4.62 ± 0.49	4.58 ± 0.52	4.59 ± 0.46
Physical activity (min/d)	126.0 ± 43.8	118.0 ± 43.0	126.9 ± 43.8	132.1 ± 43.4
Screen time (min/d)	75.7 ± 48.6	92.3 ± 58.4	74.2 ± 45.8	60.6 ± 39.3
Ethnicity (%)				
Dutch	75.9	70.7	78.4	72.8
Surinamese	4.1	7.5	3.6	2.2
Turkish	1.0	2.9	0.5	0.7
Moroccan	3.3	2.9	3.4	3.7
Other Western	11.6	10.9	10.6	16.9
Other non-Western	3.9	5.2	3.6	3.7
Maternal educational level (%)				
Low	6.9	13.3	6.1	2.2
Middle	19.9	31.2	18.7	10.3
High	73.2	55.5	75.2	87.5
Parent weight status (%)				
Normal weight	50.7	42.6	51.5	57.4
One overweight parent	37.1	43.8	36.8	30.1
Two overweight parents	12.1	13.6	11.6	12.5
Family risk factors for CVD (%)				
None affected	41.5	37.9	43.1	39.7
One parent affected	39.9	40.2	39.0	43.4
Two parents affected	18.6	21.8	18.0	16.9

Values are means with standard deviations for continuous variables and percentages for categorical variables. Abbreviations: Q, quintile; N, number; BMI, body mass index; WC, waist circumference; BP, blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CVD, cardiovascular diseases.
[a] According to age- and sex-specific BMI cut-off values [33].

Table 2
Associations of DASH score and CDQS at age 5–6 with cardiovascular outcomes at age 11–12 based on linear regressions.

DASH score	All	Q1	Q2	Q3	Q4	Q5	*P* for trend
N	869	174	208	161	190	136	
BMI (kg/m^2)	17.81 (0.09)	18.00 (0.14)	17.96 (0.14)	17.79 (0.16)	17.61 (0.15)	17.65 (0.17)	**0.016**
WC (cm)	63.1 (0.3)	63.6 (0.4)	63.5 (0.4)	62.9 (0.4)	62.7 (0.4)	62.6 (0.5)	**0.028**
Systolic BP (mm Hg)	109.3 (0.4)	110.4 (0.6)	109.0 (0.6)	109.0 (0.7)	109.8 (0.7)	107.8 (0.8)	**0.046**
Diastolic BP (mm Hg)	61.1 (0.3)	62.3 (0.4)	61.2 (0.4)	60.7 (0.5)	60.8 (0.5)	59.9 (0.5)	**<0.001**
LDL-C (mmol/L)	2.17 (0.03)	2.17 (0.04)	2.22 (0.04)	2.13 (0.05)	2.13 (0.05)	2.17 (0.05)	0.380
HDL-C (mmol/L)	1.47 (0.02)	1.42 (0.03)	1.49 (0.03)	1.51 (0.03)	1.45 (0.03)	1.47 (0.03)	0.592
Total cholesterol (mmol/L)	4.06 (0.04)	4.08 (0.06)	4.12 (0.05)	4.06 (0.06)	4.03 (0.06)	4.01 (0.06)	0.128
Triglycerides (mmol/L)	0.99 (0.04)	1.09 (0.06)	0.98 (0.06)	0.97 (0.06)	0.98 (0.06)	0.89 (0.07)	**0.032**
Fasting glucose (mmol/L)	4.90 (0.03)	4.94 (0.05)	4.88 (0.04)	4.88 (0.05)	4.97 (0.05)	4.81 (0.05)	0.350
CIMT[a] (mm)	0.456 (0.006)	0.451 (0.007)	0.455 (0.007)	0.457 (0.007)	0.460 (0.007)	0.455 (0.007)	0.095
CDQS	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***P* for trend**
N	869	148	174	179	197	171	
BMI (kg/m^2)	17.82 (0.09)	18.12 (0.15)	17.77 (0.15)	17.77 (0.15)	17.85 (0.14)	17.56 (0.16)	**0.036**
WC (cm)	63.1 (0.3)	63.7 (0.4)	63.0 (0.4)	63.4 (0.4)	62.8 (0.4)	62.7 (0.4)	0.066
Systolic BP (mm Hg)	109.3 (0.4)	109.8 (0.7)	109.2 (0.7)	109.3 (0.7)	109.4 (0.6)	109.0 (0.7)	0.532
Diastolic BP (mm Hg)	61.2 (0.3)	61.7 (0.5)	61.5 (0.5)	60.9 (0.5)	61.4 (0.5)	60.4 (0.5)	0.067
LDL-C (mmol/L)	2.18 (0.03)	2.15 (0.05)	2.13 (0.05)	2.16 (0.04)	2.18 (0.04)	2.24 (0.05)	0.081
HDL-C (mmol/L)	1.47 (0.02)	1.46 (0.03)	1.46 (0.03)	1.46 (0.03)	1.47 (0.03)	1.49 (0.03)	0.323
Total cholesterol (mmol/L)	4.07 (0.04)	4.09 (0.06)	3.99 (0.06)	4.07 (0.06)	4.09 (0.05)	4.09 (0.06)	0.462
Triglycerides (mmol/L)	0.99 (0.04)	1.12 (0.06)	0.94 (0.06)	1.01 (0.06)	1.02 (0.06)	0.87 (0.06)	**0.044**
Fasting glucose (mmol/L)	4.90 (0.03)	4.96 (0.05)	4.89 (0.05)	4.94 (0.05)	4.86 (0.05)	4.87 (0.05)	0.108
CIMT[a] (mm)	0.455 (0.006)	0.452 (0.007)	0.453 (0.007)	0.455 (0.006)	0.461 (0.007)	0.456 (0.007)	0.064

Values are estimated means from regressions with standard errors. *P*-values were calculated considering diet quality in quintiles a continuous variable. *P*-values < 0.05 are highlighted in bold. Abbreviations: Q, quintile; N, number; BMI, body mass index; WC, waist circumference; BP, blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima media thickness. All values are adjusted for gender, educational level of the mother, total energy intake and baseline value of the studied risk factor (measured at age 5–6) and age, physical activity, screen time and sexual maturation (measured at age 11–12).
[a] Not adjusted for baseline value, additionally adjusted for person assessing CIMT.

4. Discussion

4.1. Key results

We demonstrated that higher diet quality at age 5–6 was associated with modest differences in several risk factors for CVD at age 11–12. Higher DASH scores at age 5–6 were associated with lower BMI, WC, systolic and diastolic BP and triglyceride concentrations at age 11–12. Higher CDQS was associated with lower BMI and lower triglycerides. Furthermore, both dietary quality indices revealed a negative association with dyslipidaemia in pre-adolescents; higher DASH scores were also inversely associated with prehypertension. We found no statistically significant relationships between diet quality and LDL-C, HDL-C, total cholesterol, fasting glucose or CIMT.

4.2. Interpretation of findings

Higher diet quality was associated with lower BMI after 6 years follow-up. This finding is in line with an Iranian study on the longitudinal relationship between the DASH score and cardiovascular outcomes in adolescents aged 10–18 years [14]. Nguyen et al. used the CDQS in another sample of Dutch children and found a trend contrary to our findings; they showed a positive relationship between diet quality at age 8 years and BMI at the age of 10 years, which was completely driven by a higher fat-free mass [19]. In that sample, after stratification by sex, only the associations in girls remained statistically significant, suggesting that there might be already impact of peri-pubertal changes. Differences with our findings may be due to the slight age differences of both dietary and outcome assessment and the fact that we adjusted our analyses for pubertal stage, which was not the case in the study of Nguyen et al. The difference in prevalence of overweight was small, i.e. 12.8% in our sample compared to 14.5% in Nguyen's, and, although using slightly different BMI cut-offs, not considered large enough to explain the difference between findings of the two studies [33,42]. Our study showed an inverse relationship between both dietary quality indices and plasma triglyceride concentrations which is in agreement with a study using a diet quality score based on Australian dietary guidelines [11]. Not all previously published studies using the DASH score did find a relationship with levels of triglycerides in children [12,14]. The DASH score only takes into account red and processed meat as reflection for fat intake, whereas the CDQS and the diet quality score based on Australian dietary guidelines take into account both meat and fat consumption. Although, the CDQS does not specifically address hard fats or butter, the difference in design of these indices might explain the different findings.

Table 3
Associations of DASH score and CDQS at age 5–6 with risk for cardiovascular outcomes at age 11–12 based on logistic regressions.

DASH score	aOR	95% CI	% with outcome	*P*-value
Overweight	0.87	0.73–1.05	12.8%	0.159
Prehypertension	0.77	0.64–0.93	13.5%	**0.006**
Dyslipidaemia	0.79	0.65–0.95	10.5%	**0.012**
High risk CIMT[a]	1.11	0.91–1.36	10.3%	0.293
Metabolic syndrome	0.81	0.65–1.01	9.7%	0.064
CDQS	**aOR**	**95% CI**	**% with outcome**	***P*-value**
Overweight	0.86	0.72–1.04	12.8%	0.113
Prehypertension	0.87	0.72–1.04	13.5%	0.115
Dyslipidaemia	0.79	0.66–0.95	10.5%	**0.014**
High risk CIMT[a]	1.12	0.92–1.37	10.3%	0.248
Metabolic syndrome	0.89	0.72–1.10	9.7%	0.282

Abbreviation: aOR, adjusted odds ratio; CIMT, carotid intima-media thickness. *P*-values < 0.05 are highlighted in bold. All values are adjusted for gender, educational level of the mother, total energy intake and baseline value of the studied risk factor (measured at age 5–6) and age, physical activity, screen time and sexual maturation (measured at age 11–12).
[a] Not adjusted for baseline value, additionally adjusted for person assessing CIMT.

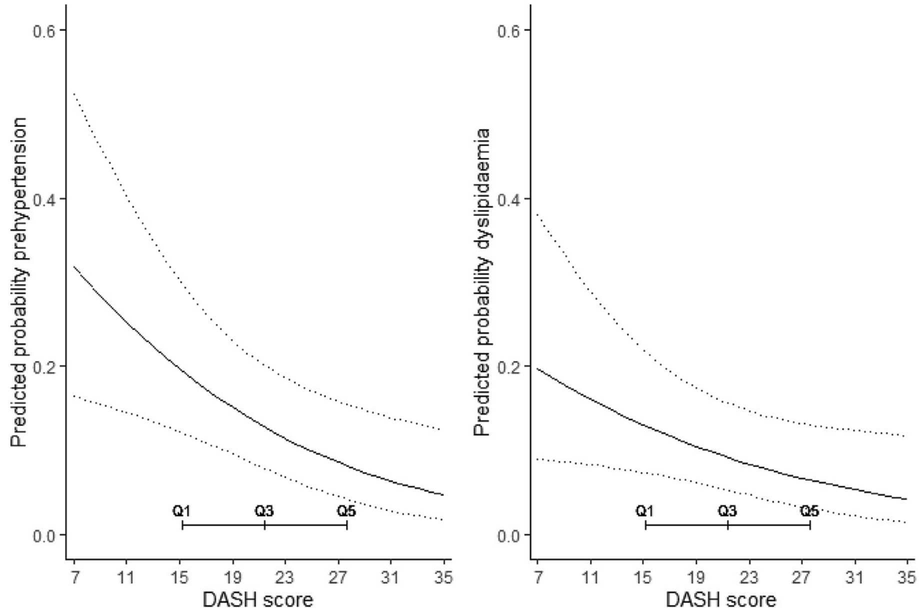

Fig. 1. Predicted probability of prehypertension and dyslipidaemia at age 11–12 based on DASH score at age 5–6. Predicted probability figure was based on the following values for the covariates in the model: boy, mean of age, screen time, physical activity and pubertal stage, middle maternal educational level and absence of prehypertension respectively dyslipidaemia at age 5-6.

Corresponding to other research, diet quality according to the DASH score was associated with lower systolic and diastolic BP and risk of hypertension in preadolescents in our study [12,17]. These results support the potential beneficial effect of the DASH diet in lowering BP in children, as already has been verified in adults [43]. In their longitudinal study, Farhadnejad et al. observed no relationship between the DASH score and the risk of dyslipidaemia at age 10–18, which is contrary to our findings [14]. Since lipid concentrations in children are usually favourable and their study sample only comprised 430 children, the low number of children with dyslipidaemia could have caused the inability to demonstrate an association.

Regarding the association of diet quality and CIMT, in agreement with our findings, two previously conducted studies indicate that no evident association exists in preadolescents [44,45]. The small differences found in CIMT and relatively short period of follow-up may explain the fact that a relationship between diet quality and CIMT has not yet been affirmed in children.

Excluding total energy intake and maternal educational level from the regression models demonstrated additional associations between higher CDQS and lower WC and diastolic BP, whereas these associations persisted with the DASH score. This could imply that the DASH score is a stronger determinant for cardiovascular outcomes in preadolescents than the CDQS, or that the DASH score is less strongly associated with energy intake and maternal education than the CDQS. Moreover, total energy intake and maternal educational level are determinants for the child's dietary pattern [39,41]. With that, adjustment for these factors is to a certain extent over-adjustment and therefore our results are presumably a conservative estimation.

4.3. Strengths and limitations

Our study had several strengths. Firstly, we were able to study the association between diet quality and outcomes while correcting for baseline levels of all outcomes (except CIMT), which allowed us to account for reverse causality to some degree and provide more evidence for causality compared to evidence from cross-sectional studies. In addition, the availability of many covariates enabled us to adjust for relevant confounding factors. As different dietary quality indices assess diets in different ways, another advantage was that we applied two indices to examine diet quality. The DASH score is calculated on the basis of population intakes and is a relative measure of diet quality, whereas the CDQS is based on an absolute measure (meeting dietary guidelines). Despite their differences in approach, the two indices were highly correlated. To overcome the difference in scoring between the two indices, we divided them both in quintiles and observed overall consistent associations with cardiovascular outcomes. This implies that high diet quality, in general and independently of dietary quality index used, is important in CVD prevention, even at an early age. Finally, we used a validated FFQ that assessed an extensive variety of foods regularly consumed by children [24].

However, some limitations of our study must be acknowledged. The external validity of our study may be low, since we mainly included children from higher educated mothers. Given that lower maternal educational level is associated with lower diet quality, we assume that our selection of children possibly represent an underestimation of the effect of diet quality on cardiovascular outcomes [18]. Considering the subjective nature of self-reporting, our physical activity data may have hinged on some bias. Although both valid and commonly used, the use of two different capillary blood analysis kits at age 5–6 and 11–12 might have influenced our results. Another limitation of our study is the fact that we had CIMT measurements from the age of 11–12 only. Due to this it was not possible to adjust for baseline CIMT measurements and solid longitudinal results with this outcome were not available. Considering that CIMT might be a possible powerful indicator for future cardiovascular outcomes already in children, revealing associations with this measurement is important and could be of great clinical value.

4.4. Implications

We found that diet quality is already at a young age associated with cardiovascular risk factors. These risk factors in childhood have shown to predict CVD risk in adulthood [5]. Taking this into account and considering that diet is a modifiable feature, it is of great importance to make improving diet quality in childhood a priority in public health.

As we are one of the first to investigate the association between diet quality in childhood and cardiovascular outcomes in pre-adolescents, our findings need to be confirmed. Future research should also assess whether dietary quality indices are reliable tools in health care settings to predict cardiovascular outcomes in children. Moreover, future studies should actively involve subjects with lower educational level to assure a greater generalisability of the results to the general population.

5. Conclusions

In conclusion, higher diet quality in children at age 5–6 years was associated with lower BMI, lower plasma concentrations of triglycerides and lower risk of dyslipidaemia in preadolescents. Our findings emphasize the importance of diet quality in childhood in the possible prevention of negative cardiovascular outcomes.

Statement of authorship

JJAK, TGMV and MN were involved in the set-up of the study. JJAK analysed the data. JJAK, TGMV and MN contributed to the interpretation of data and drafting the article. MN and TGMV interpreted data and reviewed and edited on all drafts. TGMV supervised data collection and provided the data. ANN, TV and BAH gave their expert opinion and commented on drafts. All authors approved the final version of the manuscript.

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Declaration of competing interest

The authors (JJAK, MN, ANN, TV, BAH, TGMV) declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2021.02.011.

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