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Potato consumption is not associated with elevated cardiometabolic risk in adolescent girls

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Abstract

We examined the association between potato consumption in two different age periods during adolescence and risk of obesity and cardiometabolic dysfunction in White and Black girls. We used data from the biracial prospective National Growth and Health Study. Average potato consumption was derived from multiple 3-d food records in two age periods, 9–11 and 9–17 years, and included white and sweet potatoes from all sources. Multivariable logistic regression models were used to estimate OR for becoming overweight, developing prehypertension, elevated TAG levels or impaired fasting glucose (IFG) at 18–20 years of age according to the category of daily potato intake. We also stratified by cooking method (fried/non-fried) and race. ANCOVA was also used to estimate adjusted mean levels of BMI, systolic blood pressure, diastolic blood pressure, log-transformed TAG, the TAG:HDL ratio and fasting glucose levels associated with potato intake category. Higher potato consumption was associated with higher fruit and non-starchy vegetable intakes and higher Healthy Eating Index scores in Black girls. There were no statistically significant associations overall between moderate or higher (*v.* lower) intakes of potatoes and risks of overweight, prehypertension, elevated fasting TAG, high TAG:HDL ratio or IFG. Also, no adverse associations were found between fried or non-fried potato intake and cardiometabolic outcomes. Potato consumption has been the subject of much controversy in recent years. This study adds evidence that potato consumption among healthy girls during the critical period of adolescence was not associated with cardiometabolic risk.

Key words: Potatoes: Cardiometabolic risk: Cohort study: Adolescent girls: Nutritional Epidemiology: Race

Potatoes are considered to be less healthy than most vegetables(1). The 2015–2020 dietary guidelines for Americans encourage the consumption of starchy vegetables including potatoes and recommend reducing the consumption of fried potatoes(2). Nonetheless, these guidelines acknowledge that the evidence linking fried potatoes with childhood obesity is limited.

In general, potatoes are considered to have a high glycaemic index (GI), a factor that is proposed to promote excess weight gain(3). However, a systematic review of potato consumption and overweight/obesity, type 2 diabetes mellitus and CVD risk among adults concluded that results are inconsistent(4). They did, however, find some evidence for a possible association between intake of French fries and excess weight gain, although confounding could not be ruled out as an explanation for this association. Finally, there is no consistent evidence that potato consumption is associated with excess weight gain among children, which warrants further investigation.

Adolescence is a critical period for the evolution of cardiometabolic risk (CMR). Blood pressure, for example, rises steadily throughout adolescence. The same is true for other risk factors, especially following puberty. A survey in NHANES has shown that one in twenty-five adolescent girls aged 12–19 years old had impaired fasting glucose (IFG) and those with IFG had features of insulin resistance and higher cardiovascular risk(5). Therefore, lifestyle factors, including diet, that influence the changes in blood pressure and other risk factors during this critical period of adolescence will be important determinants of high blood pressure, type 2 diabetes mellitus and dyslipidaemia during the young adult years.

Previous studies have shown that white potatoes represent 32 % of vegetable consumption among children and adolescents in the USA(6). Importantly, they provide a main source of key nutrients, including fibre, K and Mg, which have been linked with blood pressure and glucose-related outcomes(7–9). Previous results suggest that potato consumption could have blood pressure lowering effects through its K content(8,9).

Abbreviations: CMR, cardiometabolic risk; cup-eq, cup-equivalent; DBP, diastolic blood pressure; GI, glycaemic index; HEI, Healthy Eating Index; IFG, impaired fasting glucose; SBP, systolic blood pressure.

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Total fruit and vegetable intake, including potatoes, among adolescents, has also been associated with lower blood pressures over time[10–12], as well as lower levels of inflammatory biomarkers and oxidative stress even at early ages. To our knowledge, no previous prospective study has investigated the association between potato consumption and CMR factors among adolescent girls.

The overall goal of this study was to evaluate the association between potato consumption among adolescent girls as a part of a healthy diet and key cardiometabolic outcomes at the end of adolescence. Specifically, we evaluated the association between potato consumption during two age periods (9–11 years, and average intake from 9–17 years) in young Black and White girls and risks of overweight, prehypertension, elevated fasting TAG, an elevated TAG:HDL ratio and elevated fasting glucose levels in later adolescence (18–20 years of age). In younger girls, we were also able to evaluate whether these associations differed for the consumption of fried and non-fried potatoes.

Methods

Study population

The analyses were conducted using data from the National Heart, Lung, and Blood Institute's Growth and Health Study, a longitudinal study of the development of obesity and other cardiovascular-related outcomes in adolescent girls. Beginning in 1987–1988, the study enrolled 2379 subjects at 9–10 years of age from three representative urban and suburban clinical sites. The eligibility criteria for the participants' enrolment in the National Heart, Lung, and Blood Institute's Growth and Health Study cohort were as follows: (1) self-identified as Black or White (and not Hispanic or of other ethnic groups); (2) racially concordant biologic parents, (3) ages 9 or 10 years at the time of enrolment; and (4) a parent or guardian who was willing to complete a demographic questionnaire and sign an informed consent. Approximately equal numbers of Blacks and Whites were enrolled; subjects were followed annually until 18–20 years of age. Details of the original study design and methods have been previously published[13].

Analyses were carried out for two different exposure periods among those girls with complete data in both age periods. For girls at 9–17 years of age, we included those with data for total potato intake during that age period while for girls at 9–11 years of age, we included those with data on the intake of fried and non-fried potatoes as well as total potato intake during that age period. Further, for analyses of mean total potato consumption at 9–17 years of age, we excluded the following girls: (a) < 2 sets of 3-d diet records at 9–17 years of age or missing either the first or last set of diet records during that age period (n 49), (b) consumed > 1 cup-equivalent (cup-eq) of potatoes per day (n 85), (c) missing data on confounding variables (n 2 missing data on TV/video watching), (d) missing BMI, systolic (SBP) or diastolic (DBP) blood pressure measures at the end of adolescence (n 152), and (e) for analyses of lipids and glucose, those missing those outcomes (n 663 and 477 for lipids and glucose, respectively). Thus, the final sample size for the analyses of weight and blood pressure was 2091 girls, while that for lipids was 1428 girls and for glucose, 1614 girls.

Exclusions for the analyses of mean potato consumption at 9–11 years were as follows: (a) $<$ two of four sets of 3-d diet records (n 75), (b) consumed > 1 cup-eq of potatoes/d (n 54), (c) missing data on confounders (n 2 missing TV/video watching data), (d) missing outcome data for BMI, SBP or DBP at 18–20 years of age (n 179), and (e) for analyses of lipids and glucose, missing data for those outcomes (n 621 and 446 for lipids and glucose, respectively). Thus, the final sample sizes were 1989 girls for analyses of body weight and blood pressure, 1543 girls for analyses of glucose and 1368 girls for analyses of lipids. The current analyses were approved by the Institutional Review Board of Boston University.

Dietary assessment

Diet was assessed at baseline and during years 2–5, 7, 8 and 10 using 3-d dietary records, a gold-standard approach for estimating dietary intake[14]. Instructions were provided by a trained study nutritionist, and girls used standard measuring cups and spoons to estimate portion sizes. When necessary (especially at younger ages), assistance was obtained from a parent on recipes, brands and other details of the foods eaten. After the dietary records were returned, a study nutritionist reviewed the records for consistency and completeness and then carried out an in-depth debriefing. The research nutrition staff then made a determination of the reliability of each diet record; a small number of records deemed to be unreliable were excluded[15]. Data from the included records were entered into the Nutrition Data System of the University of Minnesota[16]. Nutrient intakes were derived from the Nutrition Data System using the version of the nutrient database that was appropriate to the year of data collection. The investigators at Boston University derived USDA Food Pyramid servings by linking Nutrition Data System food codes generated from the entry of the diet records with those in the USDA's 'Pyramid Serving Database for USDA Survey Food Codes, Version 2'[17]. The intake of potatoes (both white and sweet potatoes) was extracted from total vegetable servings. For these analyses, we estimated each girl's usual potato intake as the mean from diet records collected during two age periods: aged 9–11 years and 9–17 years. For analyses of fried and non-fried potato consumption, we used data from the first 2 years of the study on cooking methods associated with each food code to classify the type of potatoes consumed. Fried potatoes included such things as potato chips, French fries and pan-fried potatoes, while non-fried potatoes were typically those that were baked, boiled or mashed.

Outcome ascertainment

The outcomes including measures of body fat, BP, fasting glucose and lipid levels were assessed in later adolescence (at 18–20 years of age). For a small number of subjects ($< 5\,\%$ for each outcome) who were missing data at 18–20 years of age, data were substituted from the age of 17 or 21 when available.

Anthropometric measures of body fat and body composition were measured annually, including height and weight, waist circumference, skinfold measures and bioelectrical impedance analysis for estimating percentage body fat. BMI was calculated as the ratio of weight in kg by the square of height in m. Overweight in later adolescence was defined as a BMI at or above the 85th percentile for age and sex based on data from 2000 CDC growth charts(18).

Blood pressure was measured annually following a standardised protocol with a mercury sphygmomanometer (Baum Desktop Model, V-Lok Cuffs). Three measurements were taken with a 30-s rest in between. Prehypertension (including cases of hypertension itself) by the time of later adolescence was defined as having SBP or DBP at or above 120 and 80 mmHg, respectively, or being at or above the 90th percentile for age, sex and height-specific SBP or DBP based on data from the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents(19).

Blood specimens were collected after an 8-h fast at examination visits 7 (1993–1994) and 10 (1996–1997). Data on lipids (TAG and HDL) and glucose were derived from exam 10 for 99 % of girls, respectively. Compliance rates for blood drawing were approximately 76 % throughout the study. TAG were ascertained enzymatically (Abbott A-Gent Triglyceride Reagent Set) and elevated levels were defined as ≥ 110 mg/dl at 18–20 years of age. The ratio of TAG:HDL has been reported as a useful marker for identifying children or adolescents at risk for adverse cardiometabolic outcomes including dyslipidaemia, hypertension, the metabolic syndrome and insulin resistance or CVD(20–23). We calculated the TAG:HDL ratio for each girl and log-transformed the ratio due to non-normality(24). We defined a high ratio of log-transformed TAG:HDL as values $\geq 2{\cdot}0$(25). Fasting blood specimens were also used for the determination of glucose using the glucose oxidase method (Hitachi 704 Chemistry Analyzer from Roche Diagnostics). We defined IFG as an 8-h fasting glucose $\geq$ 100 mg/dl.

Potential confounding variables

In this study, race was self-identified as Black or White. Socio-economic status at exam 1 (1987–1988) was classified as low, moderate or high using a previously described algorithm that considered both household income and education(26).

Data on physical activity and television viewing were collected at each annual exam visit. Physical activity was assessed using the Health Activity Questionnaire, an instrument that was validated for use with adolescent girls for the measurement of participation in structured games, sports and classes. The Health Activity Questionnaire score was calculated by multiplying an estimate of the metabolic equivalent level for each recorded activity by the weekly frequency of participation, and weeks of participation per year. Time spent watching television/videos was assessed annually by asking the usual number of hours watched in a typical week. Each girl's physical activity and TV watching time were taken as the mean from all exams collected during the exposure period (9–17 and 9–11 years of age). Age- and sex-specific BMI *z*-scores were calculated based on the CDC growth charts(18) using the Lambda, Mu, Sigma method(27). Finally, foods and nutrients from the diet records were also used to explore potential confounding by dietary factors and diet quality, estimated with the 2015 Healthy Eating Index (HEI-2015)(28).

Statistical analysis

Statistical analyses were conducted using SAS statistical software (version 9.4; SAS Institute). Descriptive data on the intake of potatoes were used in sensitivity analyses to determine the cut-off values for the three categories of mean potato intake at ages 9–11 (low: $< 0{\cdot}17$; moderate: $0{\cdot}17$–$< 0{\cdot}33$; high: $0{\cdot}33$–$<$ $1{\cdot}0$ cup-eq/d) and at ages 9–17 (low: $< 0{\cdot}25$; moderate: $0{\cdot}25$–$<$ $0{\cdot}5$; high: $0{\cdot}5$–$< 1{\cdot}0$ cup-eq/d). The lowest category was used as the reference group for each analysis.

Outcome measures at 18–20 years of age were used to classify adolescents as being overweight, having prehypertension, elevated TAG levels, elevated TAG:HDL ratio or IFG as described above. Multiple logistic regression was used to estimate the adjusted OR for each of these outcomes at 18–20 years of age according to mean total potato intake category during two age periods (9–11 and 9–17). The association between fried *v.* non-fried potato intake and CMR outcomes were also assessed using available data on cooking methods from diet records collected at 9–11 years of age. Data on the cooking method were not available at older ages.

ANCOVA modelling was used to estimate adjusted mean BMI, SBP, DBP, log-transformed TAG and TAG:HDL ratio, and glucose levels from all available measures at 18–20 years of age associated with potato intake overall and stratified by cooking method at 9–11 years of age. For supplementary analyses, we also compared mean race-specific CMR outcomes associated with total potato consumption during the two age periods. Finally, effect modification between potato consumption at 9–11 years of age and two dietary factors were explored. To optimise statistical power, we used sensitivity analysis to dichotomise potato intake for the assessment of effect modification. Based on these analyses, total potato consumption was dichotomised as lower ($< 0{\cdot}17$ cup-eq/d) *v.* higher ($0{\cdot}17$ to < 1 cup-eq/d) potato intake. Sensitivity analyses were also used to determine the most appropriate cut-off values for the potential effect modifiers, including HEI scores (< 45 *v.* ≥ 45) and fruit and vegetable intakes ($< 1{\cdot}5$ *v.* $\geq 1{\cdot}5$ cup-eq/d). The dichotomous dietary variables were cross-classified with potato intake to evaluate the independent and combined effects of these factors.

All models were adjusted for race and mean age during the exposure period. We then evaluated the extent to the age and race-adjusted parameter estimates were altered by potential confounders, including socio-economic status, hours of TV/video watched per day, mean BMI at 9–17 years of age, HEI-2015 scores, change in height, physical activity per day, percentage of energy from fat, saturated fat and carbohydrate, intakes of fibre, red and processed meats, fruit and non-starchy vegetables, added sugars and total energy. The final multivariate model included those factors that altered the OR estimates by approximately 10 % or more and included age, race, hours of TV and video watched per day, percentage of calories from fat, and fruit and vegetable intake. Potential confounding variables that did not lead to changes in the effect estimates or that were strongly colinear were not included in the final models. Models for fried potatoes were also adjusted for the intake of non-fried potatoes and vice versa. The assumptions of ANCOVA and logistic regression models were tested, and no violations of the assumptions were found.

Results

Potato intake was normally distributed, and mean intakes among White and Black adolescent girls, aged 9–11 years old, were 0·27 (SD 0·21) and 0·30 (SD 0·22) cup-eq per day, respectively. Table 1 shows the baseline participant characteristics according to potato intake categories in White and Black 9–11-year-old adolescent girls. Overall, baseline age and physical activity differed little across potato intake categories. More Black girls than White girls were from lower socio-economic status families and Black girls who consumed more potatoes tended to have slightly lower BMI *z*-scores than those who consumed less. In general, dietary patterns differed across categories of potato intake in both White and Black girls. Higher intakes of potatoes were associated with lower intakes of protein but higher intakes of dietary fat, while carbohydrate intake remained the same across categories of intake. Girls with higher potato intakes consumed more dietary K as well as higher fibre intakes and higher intakes of micronutrients such as vitamins B_6 and C, and Mg. Overall, Black girls in particular with the highest potato intakes had a better diet quality as assessed by HEI scores.

Table 2 examines the overall adjusted OR for overweight, having prehypertension, elevated TAG or IFG by late adolescence associated with potato consumption during the two age periods. Overall, there were no consistent or statistically significant adverse effects of potato consumption on risk of these cardiometabolic outcomes, after adjusting for confounding by age, race, hours of TV/video watched per day, percentage of calories from fat, and fruit and vegetable intake.

Figure 1 extends the analyses from Table 2 through stratifying by race. Figure 1 (a) and (b) shows that there are no associations between potato consumption at 9–11 years of age and CMR outcomes in later adolescence in either Black or White girls, while Fig. 1 (c) and (d) shows the same results for potato consumption at 9–17 years of age.

Figure 2 examines the cardiometabolic outcomes in late adolescence associated with fried and non-fried potato consumption in early adolescence. There was no indication that potato consumption, whether fried or not, was associated with a subsequent increased risk of overweight, prehypertension, elevated TAG or IFG. Table 3 further explores the association between fried and non-fried potatoes and adjusted mean levels for each outcome, including BMI, SBP, DBP, fasting glucose, and log-transformed TAG and the TAG:HDL ratio. There were no statistically significant associations for any of these outcomes.

Online Supplementary Table S1 shows the girls' adjusted mean levels of CMR factors at 18–20 years of age associated with categories of total potato intake at 9–11 and 9–17 years of age, overall and stratified by race. There were no statistically significant associations between potato consumption at 9–11 years of age and mean BMI, BP, TAG or glucose levels after adjusting for confounding. At 9–17 years of age, White girls who consumed $\geq 0{\cdot}5$ cups of potatoes per day had an SBP that was 1·2 mmHg higher than that of girls consuming $< 0{\cdot}25$ cup/d.

Finally, online Supplementary Table S2 explores whether the effects of potato intake at ages 9–11 years on CMR outcomes were modified by other dietary factors. Specifically, we examined the independent and combined effects of HEI scores (and total fruit and vegetable intakes) with potato consumption. These analyses show that there were no statistically significant effects of potato intake regardless of HEI scores or fruit and vegetable intakes.

Discussion

This is the first long-term population-based study to assess the association between potato consumption and CMR factors among Black and White adolescent girls in the USA. In this study, higher potato consumption was associated with higher intakes of fruit and non-starchy vegetables and higher HEI scores in early adolescence, particularly in Black girls. Specifically, White girls who consumed more potatoes tended to have lower diet quality scores on the HEI, but this was not the case for Black girls, where higher potato intakes were associated with higher HEI scores. In general, all girls with higher potato intakes also had higher intakes of important nutrients, including K, Mg, vitamin C and fibre, some of which are often inadequate in adolescents(29).

Overall, we observed no adverse associations between potato consumption and increased odds of developing abnormal cardiometabolic outcomes by the time of late adolescence in this cohort of White and Black adolescent girls. Further, intakes of fried and non-fried potatoes were not associated with adjusted mean levels of CMR factors or risks of becoming overweight, developing hypertension or having elevated TAG or fasting glucose. We observed a small increase in SBP associated with higher potato intake (*v.* lower) among White but not Black girls.

There is a paucity of data among children and adolescents on the effects of potato consumption on CMR. One cross-sectional study of 205 Iranian girls aged 11–13 years old found no adverse effects of potato consumption (total, boiled or French fries) on DBP and SBP, and no relationship between total potato intake and high blood pressure risk. In contrast with the current results, they found a positive association between higher total potato intake and adiposity measures, although the cross-sectional design and the small sample size limit the validity of those results(30). Further, a prospective cohort study, including 8203 girls and 6715 boys, aged 9–14 years old, examined intakes of vegetables, with and without potato consumption and found no association between intake and changes in BMI *z*-scores(31). In the current study, we found no adverse effects of higher potato intakes on BMI.

A recent crossover trial of 11–13-year-olds found that post-meal appetite was lowest following the consumption of boiled and mashed potatoes compared with other similar dietary exposures (i.e. French fries, pasta, rice). The authors also found that

Table 1. Characteristics of White and Black girls at ages 9–11 years according to potato consumption in the NGHS study
(Mean values and standard deviations)

	White girls							Black girls						
	Potato consumption (cup-equivalents/d)							Potato consumption (cup-equivalents/d)						
	< 0·17		0·17–< 0·33		0·33–1·0			< 0·17		0·17–< 0·33		0·33–1·0		
	n 376		*n* 288		*n* 323			*n* 319		*n* 298		*n* 385		
Baseline	Mean	SD	Mean	SD	Mean	SD	*P**	Mean	SD	Mean	SD	Mean	SD	*P**
Age (years)	10·4	0·6	10·5	0·6	10·5	0·6	0·30	10·6	0·6	10·6	0·6	10·6	0·6	0·57
BMI (kg/m^2)	18·4	3·4	18·5	3·6	18·3	3·2	0·82	19·8	4·3	20·3	4·4	19·5	4·3	0·08
BMI *z*-score	0·2	1·1	0·2	1·1	0·2	1·0	0·97	0·5	1·1	0·7	1·1	0·4	1·1	0·0388
Activity (METs/d)	31·5	15·7	30·2	14·9	31·9	15·3	0·37	27·7	15·5	28·5	15·3	29·0	15·5	0·58
TV/video (h/d)	3·5	1·8	3·8	1·9	3·8	1·9	0·07	5·4	2·1	5·9	2·1	5·8	2·1	0·0056
SES (column % low)	6·9 %		10·4 %		14·9 %		0·09	35·4 %		29·9 %		32·7 %		0·11
Diet (daily)														
Energy (kJ)	7244·0	1574·0	7444·0	1529·0	7965·0	1652·0	< 0·0001	7276·0	1938·0	7712·0	1865·0	8601·0	2082·0	< 0·0001
Protein (% energy)	14·8	2·4	14·3	2·3	14·2	2·5	0·0043	14·6	2·4	14·2	2·3	13·9	2·2	0·0005
Carbs (% energy)	52·1	5·8	52·1	5·5	51·6	5·6	0·40	50·4	6·2	49·9	5·5	50·0	5·6	0·49
Fat (% energy)	34·3	4·7	34·9	4·1	35·4	4·3	0·0034	35·9	4·9	36·9	4·2	37·1	4·6	0·0015
Folic acid (ug)	234·5	95·3	224·8	80·1	229·3	84·5	0·36	219·5	90·1	223·7	86·1	241·2	104·7	0·0053
Vitamin B$_6$ (mg)	1·3	0·5	1·3	0·4	1·5	0·4	< 0·0001	1·3	0·5	1·4	0·5	1·6	0·5	< 0·0001
Vitamin C (mg)	81·3	46·5	81·7	44·8	88·9	43·9	0·05	82·7	46·5	87·3	42·7	101·0	49·5	< 0·0001
K (mg)	1967·5	494·4	2032·3	485·8	2243·8	549·5	< 0·0001	1787·5	515·8	1922·9	482·6	2246·0	544·5	< 0·0001
Mg (mg)	214·5	56·1	215·2	56·9	226·6	58·7	0·0095	198·2	61·0	206·9	66·0	225·4	61·7	< 0·0001
Potatoes (cup-eq)	0·08	0·06	0·24	0·05	0·52	0·16	< 0·0001	0·07	0·06	0·25	0·05	0·53	0·17	< 0·0001
FnsVeg (cup-eq)	1·5	0·8	1·4	0·8	1·5	0·8	0·17	1·3	0·7	1·4	0·8	1·6	0·8	0·0004
Dietary fibre (gm)	11·2	3·8	11·2	3·7	12·2	3·8	0·0002	10·2	3·7	10·9	3·8	12·4	4·2	< 0·0001
Dairy (cup-eq)	1·4	0·7	1·5	0·6	1·6	0·6	0·0001	1·1	0·7	1·2	0·6	1·4	0·6	< 0·0001
HEI 2015 score	44·1	8·2	44·5	7·8	45·0	7·5	0·34	41·4	7·3	41·8	7·1	43·7	7·2	< 0·0001

NGHS, National Heart, Lung, and Blood Institute's Growth and Health Study; BMI, body mass index; METs, metabolic equivalents; SES, socioeconomic status; cup-eq, cup-equivalents; FnsVeg, fruit and non-starchy vegetables and HEI, Healthy Eating Index.

* *P* values were generated from ANOVA for continuous variables and chi-square tests for categorical variables.

Table 2. Risk of overweight and elevated cardiometabolic risk at 18–20 years of age according to potato intakes categories at 9–11 and 9–17 years of age in the NGHS study*
(Odds ratios and 95 % confidence intervals)

	Potato intake at ages 9–11 (cup-eq/d)				Potato intake at ages 9–17 (cup-eq/d)			
	< 0·17	0·17–< 0·33	0·33–1.0	*P*-trend	< 0·25	0·25–< 0·50	0·50–1·0	*P*-trend
Overweight								
n	695	586	708		573	870	648	
Cases	254	242	275		206	337	269	
OR*	1·00	1·12	0·99	0·90	1·00	0·97	0·93	0·59
95 % CI	Ref.	0·89, 1·42	0·79, 1·24		Ref.	0·77, 1·22	0·73, 1·20	
Prehypertension								
n	695	586	708		573	870	648	
Cases	114	101	127		68	125	104	
OR*	1·00	0·99	0·96	0·80	1·00	1·13	1·18	0·38
95 % CI	Ref.	0·73, 1·33	0·73, 1·28		Ref.	0·82, 1·56	0·83, 1·66	
Elevated TAG								
n	473	418	477		387	610	431	
Cases	89	71	78		84	91	71	
OR*	1·00	0·90	0·92	0·64	1·00	0·76	1·03	0·93
95 % CI	Ref.	0·63, 1·29	0·65, 1·31		Ref.	0·54, 1·07	0·71, 1·51	
High TAG:HDL ratio								
n	472	418	477		387	609	431	
Cases	124	102	101		116	129	92	
OR*	1·00	0·94	0·83	0·23	1·00	0·76	0·93	0·63
95 % CI	Ref.	0·69, 1·28	0·61, 1·13		Ref.	0·56, 1·03	0·66, 1·31	
Impaired fasting glucose								
n	535	457	551		432	691	491	
Cases	40	32	32		33	42	33	
OR*	1·00	0·88	0·69	0·14	1·00	0·69	0·69	0·19
95 % CI	Ref.	0·54, 1·44	0·42, 1·12		Ref.	0·43, 1·12	0·41, 1·17	

NGHS, National Heart, Lung, and Blood Institute's Growth and Health Study; cup-eq, cup-equivalents.
* Models were adjusted for age, race, hours of TV and video watched per day, percentage of calories from fat and fruit and vegetable intake.

the consumption of French fries led to the lowest post-prandial glucose and insulin levels(32). This is in line with our results, suggesting that fried potato intake is not associated with elevated fasting glucose among adolescent girls. Further, in an analysis of data from 69 313 subjects from the Swedish Mammography Cohort and a Cohort of Swedish Men, investigators found that potato consumption was unrelated to CVD risk over 13 years of follow-up(33). In contrast, analyses from the Nurses' Health Study found potato consumption (median intake 0·63 servings/d) to be associated with an adjusted 14 % increased risk of type 2 diabetes mellitus(34). Another report from the Nurses' Health Study cohorts and the Health Professionals Follow-up Study found that higher intakes of potatoes (baked, boiled or mashed or as French fries, but not potato chips) were associated with a somewhat higher long-term risk of developing hypertension(35), particularly in the Nurses' Health Study II cohort.

A proposed mechanism to explain potential adverse effects of potato intake on CMR is linked with the relatively high GI of potatoes and the higher fat content of a 'Western' diet with a greater intake of fried potatoes. However, these two explanations are somewhat contradictory. In terms of the GI of the potato, the fat content of the meal in which it is consumed or the way in which it is cooked and eaten may lower the GI. Specifically, in the USA, potatoes are typically consumed with a source of fat and/or protein (e.g. potatoes with butter or sour cream, fried potatoes, or a 'meat and potatoes' meal). Since all of these eating patterns will lower the GI of the potato(36), the concerns about health effects based on the GI of potatoes may be misplaced. In addition, potatoes, compared with other carbohydrate-rich foods, have a lower energy density because of their high water content(37). They also provide key nutrients, including K, vitamin C, P, Mg, folate and dietary fibre – all of which have been linked with beneficial effects on cardiovascular outcomes(37).

In addition to human studies, the potato and its components have also been found to have beneficial effects on weight management in animal studies. Potatoes (especially potato peels) are a rich source of phenolic compounds – flavonoids, which are the largest contributors of vegetable phenolic compounds in the American diet(38). One study showed that male and female mice fed a high-fat diet with polyphenolic-rich potato extracts for 10 weeks decreased weight gain by 63·2% and 55·8 %, respectively, compared with the high-fat diet alone. This attenuation in weight gain was associated mostly with a reduction in fat depots. In addition, both male and female mice fed the polyphenolic-rich potato extracts and a high-fat diet had an enhanced capacity for blood glucose clearance, compared with the high-fat diet group alone(39).

There are limitations to all epidemiological studies, particularly of diet, and this study is no exception. Dietary intake is determined by self-report and as a result is subject to error. However, not all dietary assessment methods are equally

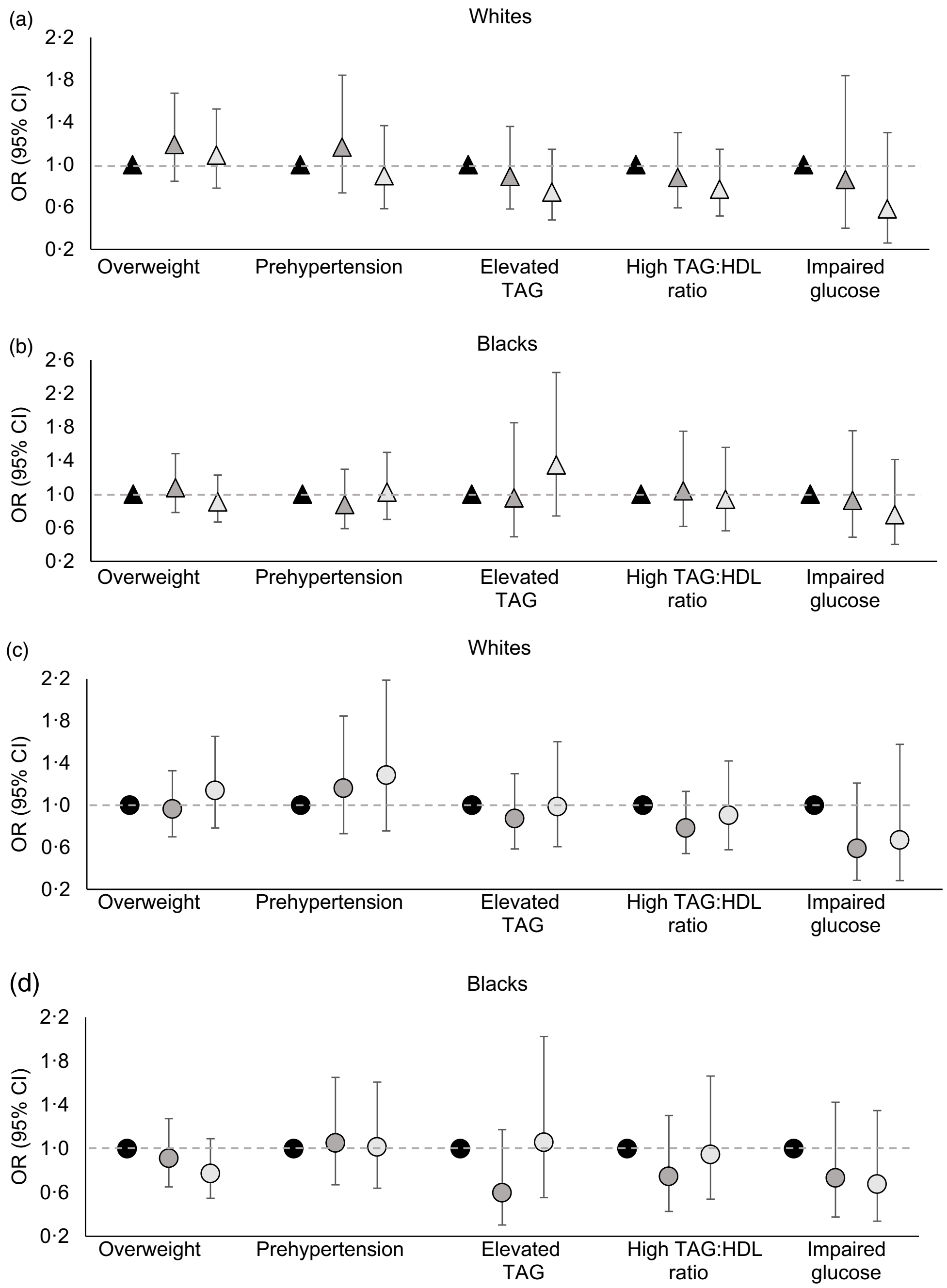

Fig. 1. Cardiometabolic risk (CMR) at 18–20 years of age according to mean total potato intake category at two age periods among Whites and Blacks. (a and b) OR for CMR factors according to potato intake at ages 9–11 in Whites and Blacks. (c and d) OR for CMR factors according to potato intake at ages 9–17 in Whites and Blacks. None of the associations reached statistical significance (*P*-trend ≥ 0·05). All models were adjusted for age, hours of TV and video watched per day, percentage of calories from fat, and fruit and non-starchy vegetable intake. cup-eq, cup-equivalents. (a and b) Potato intake (cup-eq/d) ▲, < 0·17; ▲, 0·17–0·33; △, 0·33–1·0. (c and d) Potato intake (cup-eq/d) ●, < 0·25; ●, 0·25–0·5; ○, 0·5–1·0.

susceptible to error. In particular, the dietary record approach used in this study has served as a ‘gold standard’ method for validating other dietary assessment methods[14]. Therefore, we believe that their use in this study likely provides more accurate estimates of potato intake than studies relying on other methods such as FFQ. The dietary records in this study did rely largely on reported intakes from the children and adolescents themselves, who, particularly in the early years of the study, would likely have had difficulty accurately estimating portion sizes and reporting details such as recipes, brands and preparation

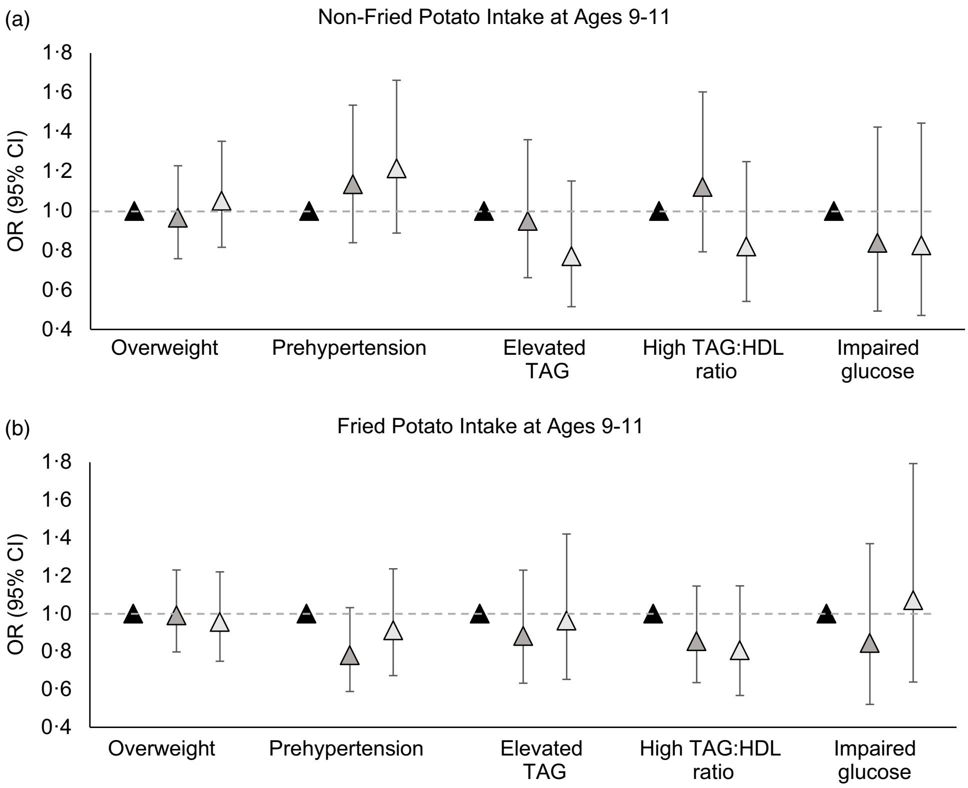

Fig. 2. Cardiometabolic risk (CMR) at 18–20 years of age according to mean non-fried and fried potato intake category at baseline (9–11 years of age). (a) OR for CMR factors according to non-fried potato intake. (b) OR for CMR factors according to fried potato intake. All models were adjusted for age, race, hours of TV and video watched per day, percentage of calories from fat, and fruit and non-starchy vegetable intake. None of the associations reached statistical significance (*P*-trend ≥ 0·05). Models for fried potatoes are also adjusted for non-fried potatoes and models for non-fried potatoes are adjusted for fried potato intake. cup-eq, cup-equivalents. (a and b) Potato intake (cup-eq/d) ▲, < 0·17; ▲, 0·17–0·33; △, 0·33–1·0.

methods. However, parents and other caregivers were actively involved in the completion of these diet records, especially during the earlier years of the study. Many studies of diet suffer from underreporting of dietary intake, but this problem has shown to be more evident when reporting intakes of snacks and sweets than other meal-related foods(40). Therefore, we believe that the assessment of potatoes in this study would be less susceptible to underreporting than some other foods. One limitation of this study is the inability to assess the effects of very high levels of intake since < 4 % of girls consumed more than one cup-equivalent of potatoes per day. We were also unable to analyse the results for sweet and white potatoes separately, due to the low consumption of sweet potatoes (13·5 % of the study population consumed small amounts of sweet potatoes). Finally, another limitation of the study was our inability to control for baseline values of fasting glucose or lipids due to missing or unreliable data at exam 1.

Another important strength of this study is its prospective design as well as the availability of multiple sets of 3-d diet records collected during 8 of the 10 years of follow-up, thus providing greater precision in the estimation of dietary intake than is seen in many studies. And while there are repeated measures of cardiovascular risk factors and most potential confounders, we cannot rule out the possibility of residual confounding.

Cardiometabolic measures in late adolescence are important determinants of adult cardiovascular risk. Thus, the identification of modifiable predictors, including diet, is particularly important. Potato consumption has been the subject of much controversy in recent years. Since potatoes are an important source of beneficial nutrients, data are especially needed to address the health effects during this critical developmental period. This study adds evidence that potato consumption, regardless of the cooking method among healthy young White and Black girls during adolescence, has no adverse effect on CMR.

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LLM and IY designed the analysis; MRS analysed the data; LLM and IY wrote the manuscript. IY, MY, RTP, MRS, and LLM participated in the interpretation of the results and editing of

Table 3. Adjusted mean levels of BMI and cardiometabolic risk factors at 18–20 years of age associated with weekly intake of fried and non-fried potatoes at 9–11 years of age (Mean values with their standard errors)

	BMI (kg/m²)			SBP (mm Hg)		DBP (mm Hg)		Log TAG (mg/dl)			Log TAG:HDL ratio		Fasting Glucose (mg/dl)		
Potato intake (cup-eq/d)	*n*	Mean*	SE	Mean*	SE	Mean*	SE	*n*	Mean*	SE	Mean*	SE	*n*	Mean*	SE
Non-fried															
< 0·17	1242	25·2	0·18	108·8	0·23	65·3	0·22	843	4·31	0·01	0·91	0·01	952	87·8	0·72
0·17 to < 0·33	393	25·0	0·31	109·5	0·40	65·7	0·40	284	4·33	0·02	0·93	0·02	313	88·6	1·25
0·33 to 1·0	354	25·2	0·33	109·3	0·43	65·8	0·42	241	4·24	0·03	0·87	0·02	278	89·9	1·33
P-trend		0·94		0·22		0·27			0·06		0·25			0·17	
Fried															
< 0·17	853	25·4	0·21	109·0	0·28	65·3	0·27	268	4·29	0·03	0·91	0·01	297	89·1	1·29
0·17 to < 0·33	657	24·9	0·24	108·7	0·31	65·6	0·31	461	4·29	0·02	0·90	0·01	517	86·7	0·97
0·33 to 1·0	479	25·0	0·29	109·5	0·37	65·7	0·37	320	4·32	0·02	0·91	0·02	366	89·9	1·18
P-trend		0·17		0·44		0·39			0·61		0·83			0·64	

cup-eq, cup-equivalents; SBP, systolic blood pressure; DBP, diastolic blood pressure.

* Means are adjusted for age, race, hours of TV and video watched per day, percentage of calories from fat and fruit and non-starchy vegetable intake. Models for fried potatoes are also adjusted for non-fried potatoes and models for non-fried potatoes are adjusted for fried potato intake.

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Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S0007114521003445

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