

# Dietary Patterns of Adolescents and Risk of Obesity and Hypertension<sup>1–3</sup>

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## Abstract

Increasingly, measures of dietary patterns have been used to capture the complex nature of dietary intake and investigate its association with health. Certain dietary patterns may be important in the prevention of chronic disease; however, there are few investigations in adolescents. The aim of this study was to describe the dietary patterns of adolescents and their associations with sociodemographic factors, nutrient intakes, and behavioral and health outcomes. Analysis was conducted using data collected in the 1995 Australian National Nutrition Survey of participants aged 12–18 y who completed a 108-item FFOQ ( $n = 764$ ). Dietary patterns were identified using factor analysis and associations with sociodemographic factors and behavioral and health outcomes investigated. Factor analysis revealed 3 dietary patterns labeled a fruit, salad, cereals, and fish pattern; a high fat and sugar pattern; and a vegetables pattern, which explained 11.9, 5.9, and 3.9% of the variation in food intakes, respectively. The high fat and sugar pattern was positively associated with being male ( $P < 0.001$ ), the vegetables pattern was positively associated with rural region of residence ( $P = 0.004$ ), and the fruit, salad, cereals, and fish pattern was inversely associated with age ( $P = 0.03$ ). Dietary patterns were not associated with socioeconomic indicators. The fruit, salad, cereals, and fish pattern was inversely associated with diastolic blood pressure ( $P = 0.0025$ ) after adjustment for age, sex, and physical activity in adolescents  $\geq 16$  y. This study suggests that specific dietary patterns are already evident in adolescence and a dietary pattern rich in fruit, salad, cereals, and fish pattern may be associated with diastolic blood pressure in older adolescents. *J. Nutr.* 138: 364–370, 2008.

## Introduction

Adolescence represents an important life stage for the development of healthy nutrition behaviors. The nutritional demands associated with rapid physical and cognitive development and maturation are substantial (1,2). In developed countries, adolescents increasingly demonstrate early signs of adverse nutrition-related conditions, including subclinical cardiovascular disease, type 2 diabetes, and obesity (3). There is evidence that nutrition behaviors track from adolescence into adulthood (4). Therefore, the promotion of healthy nutrition during adolescence has the potential to confer significant long-term health benefits.

Despite the importance of nutrition for adolescents' current and future health, many adolescents consume diets that are not consistent with dietary guidelines. For example, studies from the US, Europe, and Australia demonstrate that adolescents tend to

have lower than desirable intakes of fruits, vegetables, dairy products, and whole grains but higher than desirable intakes of soft drinks, confectionery, and fast foods (5–9). Consequently, many adolescents fall short of achieving optimal nutrient intakes for good health and development.

Previous investigations of adolescent diet have tended to focus on intakes of individual foods or nutrients. However, in recent years, the use of dietary pattern analysis has become popular for characterizing the whole diet in combination, because this approach captures complex behaviors and potentially interactive and antagonistic effects among nutrients that might impact health outcomes (10,11). Methods for studying dietary patterns, such as principal components factor analysis and cluster analysis, have become more widely used in epidemiology to summarize dietary data and investigate predictors and health outcomes associated with dietary patterns (12–16).

To date, most research on dietary patterns has focused on adults (11) and the existing literature for children (17–24) and adolescents (17,18,21,25–27) exhibits some inconsistencies. Studies of dietary patterns among adolescents have identified between 2 (21,26) and 17 (27) dietary patterns. Some studies (18,21) but not others (17) (26) found strong socioeconomic gradients in the dietary patterns identified. Associations between dietary patterns and health outcomes or risk factors, including BMI, serum cholesterol, and blood pressure, were also found in some (17,27) but not all analyses (26,27). Few studies examined

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<sup>3</sup> Supplemental Table 1 is available with the online posting of this paper at [jn.nutrition.org](http://jn.nutrition.org).

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behavioral correlates of dietary patterns, such as skipping breakfast (26) or meal frequency. Dietary patterns have been shown to reflect variations in nutrient intake (21,24,28,29), but again, there have been few investigations among children or adolescents (26). There is currently no published data to our knowledge on the dietary patterns of adolescents in Australia using multivariate analysis methods.

This study applied a dietary patterns approach to investigate the eating behaviors of adolescents. The study aimed to investigate whether adolescents demonstrated clear dietary patterns and if so, whether dietary patterns among adolescents varied according to sociodemographic and behavioral characteristics. Associations of dietary patterns with nutrient intakes and health outcomes were also examined.

## Materials and Methods

**Participants and procedures.** Data from the most recent (1995) Australian National Nutrition Survey (NNS) were analyzed (30–32). Detailed descriptions of the sampling and methodology used are described elsewhere (32–34). Ethics approval for the survey was provided by the Ethics Committee of the Australian Institute of Health and Welfare (32). The NNS consisted of a 24-h dietary recall, a FFQ, a food habits questionnaire, and a number of physical measurements (weight, height, waist circumference, and blood pressure). Only participants aged  $\geq 12$  y completed the FFQ and the food habits questionnaire. Of the 13,858 participants of the NNS, 1086 were adolescents aged 12–18 y.

**Measures.** The 108-item self-administered FFQ assessed usual frequency of intake of food and beverages over the last 12 mo. Each item had a choice of 9 frequency categories ranging from “never or less than once a month” to “6 or more times per day” but did not include information on portion sizes. The FFQ used in the Australian NNS was a modified version of an existing validated questionnaire developed for use in Australian populations with additional foods included (35). A total of 313 adolescents did not complete the FFQ and 9 participants had incomplete FFQ with 20 or more blank responses (32). Therefore, this study is based on data from 764 adolescents with a valid FFQ.

Subjects answered additional questions about a number of food habits. These questions asked about the type of milk usually consumed (whole milk, reduced fat milk, or skim milk), how often meat is trimmed of fat, the number of times food is usually consumed per day, and breakfast consumption (number of times per week food is consumed for breakfast). These questions have been evaluated and provide valid measures of food habits (36,37).

During the 24-h recall, information was collected on all food items and beverages that were consumed on the previous day. Across the study population, all days of the week and seasons were represented. The multiple-pass method consisted of the completion of a quick list of food and beverage items consumed, followed by the collection of detailed information for each item listed in the quick recall, and finally a review phase to allow respondents to report any foods that may have been forgotten (32). The method was based on that developed by the USDA (38). Nutrient intake was calculated by the Australia Bureau of Statistics using a customized food composition database (39). Energy-adjusted nutrient intakes were calculated using the residual method (40).

The 24-h recall data were used as an independent measure of dietary intake and provided a measure of the construct validity of the dietary patterns. Construct validity is the extent to which there are associations with other variables that there is reason to believe should be associated (41). As the 24-h recall data are only a single day's intake, its most appropriate use is for estimating the mean intakes for groups. Nutrient intakes from the FFQ were not available, because the questionnaire included only frequency of consumption and did not include portion size. To use this FFQ to calculate nutrient intakes, we would need to make considerable assumptions about the portion sizes and this approach is not recommended for this questionnaire (42).

Region was defined using the rural, remote, and metropolitan areas classification system that is based on factors such as population density and distance to the nearest population center (43). The Index of Relative Socioeconomic Disadvantage (SEIFA) is an area-level indicator of socioeconomic position based on the economic resources, education, occupation, family structure, and ethnicity of households (30). The lowest quintile represents areas with a greater number of families of low income and a greater number of people with little training or who are employed in unskilled occupations (30). Equivalent household income is a derived index based on the individual dollar income of all members of the income unit. The data were categorized into quintiles for this analysis. Physical activity was also assessed by self-report using standardized questions (44). Respondents were asked whether during the previous 2 wk they did any walking for sport, recreation, or fitness; moderate exercise (apart from walking); or vigorous exercise. For each of these activities, they were asked the number of times and the total amount of time spent. These data were then used to derive an overall measure of physical activity. Physical activity was measured only in adolescents aged  $\geq 15$  y ( $n = 400$ ) due to lack of appropriate self-report measures for younger Australian children.

Waist circumference, height, and weight were measured with standardized protocols and BMI was calculated ( $\text{kg}/\text{m}^2$ ) (32). Blood pressure was measured twice, with the survey member seated after resting during the dietary recall using a Tycos Aneroid sphygmomanometer. If the systolic readings differed by  $>6$  mm Hg and/or the diastolic readings differed by  $>4$  mm Hg, a 3rd measurement was made. The average of the 2 measurements (or the 2 closest measurements) was used for this analysis (32). Only subjects aged  $\geq 16$  y had blood pressure measurements taken ( $n = 282$ ) due to difficulties in measurement of blood pressure in younger children. All data were collected by trained interviewers (32,45).

**Statistical analysis.** Dietary patterns were derived using factor analysis with factor loadings extracted using the principal component method and varimax rotation using data from the FFQ. We converted frequency of consumption of 86 food items to daily equivalent frequencies and entered these into the factor analysis. We chose to retain the majority of items as they appeared on the FFQ to reduce the number of subjective decisions made in determining the dietary patterns and in light of research recommending this approach (46,47). A small number of food items were excluded from the factor analysis due to very low frequency of consumption, such as soy beverages, soy beans, vegetable juice, and alcoholic beverages ( $>80\%$  of adolescents reporting consumption less than once per month) and a small number of food items were combined if they represented the same food in different forms (e.g. beef as steak or as casserole). Frequency variables were log-transformed to improve normality prior to factor analysis (11,12,48).

The number of dietary patterns identified was based on Eigenvalues  $>1.25$ , identification of a break-point in the scree plot, and interpretability (49). Items were considered to load on a factor if they had an absolute correlation  $\geq 0.30$  with that factor and were retained in the calculation of the dietary pattern score, because these items represent the foods most strongly related to the identified factor (46,50,51). Foods that cross-loaded on several factors or had absolute correlations  $<0.3$  were not included in the dietary pattern score calculation (51). Inter-item reliability for each factor was assessed by Cronbach's  $\alpha$  coefficients. Dietary pattern scores were calculated using the frequency of consumption of each of the food items and the weightings determined by the factor analysis. To investigate the ability to use these dietary patterns in other populations, a simplified dietary pattern score as suggested by Schulze et al. (49) was also calculated. This method derives a dietary pattern score based on the sum of the frequency of consumption of foods that load highly on the factor but ignores the weighting from the factor analysis. Spearman correlations between the original pattern score and the simplified score were calculated to evaluate the simplified pattern scores.

Dietary pattern scores were categorized into tertiles. Associations between dietary patterns and both sociodemographic factors and food habits were investigated using chi-square analysis. Means and standard errors of nutrient intakes (calculated from the 24-h recall and energy adjusted) and linear trends across tertiles of dietary pattern scores were calculated using ANOVA and linear regression analysis. Means (and

standard errors) of BMI, waist circumference, systolic blood pressure, and diastolic blood pressure were calculated according to tertiles of dietary pattern scores using ANOVA and adjusted for age and sex. Only those covariates associated with both the dietary patterns and the health outcomes (BMI, waist circumference, and blood pressure) were included in the adjusted models. *P*-values < 0.05 were considered significant.

## Results

**Dietary patterns.** Factor analysis revealed 3 unique dietary patterns (Supplemental Table 1). Dietary patterns for males and females were similar in relation to the number of factors identified and the foods that loaded highly. Due to the relatively small numbers of participants involved, males and females were combined for analysis. The 3 patterns were labeled based on the food items that loaded highly: a fruit, salad, cereals, and fish pattern; a high fat and sugar pattern; and finally, a vegetables pattern. These patterns explained 11.9, 5.9, and 3.9% of the variation in food intakes, respectively. Cronbach's  $\alpha$  indicated that there was high inter-item reliability (0.86 for the fruit, salad, cereals, and fish pattern; 0.82 for the high fat and sugar pattern; and 0.81 for the vegetables pattern). Spearman correlation coefficients between the original pattern score and a simplified pattern score were 0.78 for the fruit, salad, cereals and fish

pattern, 0.96 for the high fat and sugar pattern, and 0.94 for the vegetables pattern.

**Associations of dietary patterns with sociodemographic and behavioral characteristics.** Only the high fat and sugar pattern showed sex differences, with males more likely to have high scores for this pattern (Table 1). Only the fruit, salad, cereals, and fish pattern was associated with age, with younger participants more likely to have high scores. None of the 3 dietary patterns were associated with SEIFA quintile or household equivalent income. Region was associated only with the vegetables pattern, with a greater percentage of participants from the rural and remote areas having high vegetables pattern scores. Only the high fat and sugar pattern was associated with physical activity, with a greater percentage of participants in the medium or high activity categories having higher dietary pattern scores.

With respect to food habits, there were no associations between any of the dietary patterns and trimming fat from meat or the type of milk consumed. Participants with high scores on the high fat and sugar pattern ( $\chi^2 = 30.9$ ;  $P < 0.0001$ ) and the fruit, salad, cereals, and fish pattern ( $\chi^2 = 10.2$ ;  $P = 0.04$ ) reported consuming food a greater number of times per day than did those with low scores; however, there was no association with the vegetables pattern. Participants with high scores on the

**TABLE 1** Sociodemographic characteristics of adolescents in the Australian NNS according to tertiles of dietary pattern score<sup>1</sup>

| Characteristic                       | <i>n</i> | Fruit, salad, cereals, and fish |      |       | High fat and sugar |      |       | Vegetables |      |       |
|--------------------------------------|----------|---------------------------------|------|-------|--------------------|------|-------|------------|------|-------|
|                                      |          | T1                              | T2   | T3    | T1                 | T2   | T3    | T1         | T2   | T3    |
| Sex                                  |          |                                 |      |       |                    |      |       |            |      |       |
| Males                                | 397      | 36.5                            | 31.0 | 32.5  | 24.4               | 34.8 | 40.8* | 33.5       | 36.0 | 30.5  |
| Females                              | 367      | 30.0                            | 36.0 | 34.1  | 43.1               | 31.9 | 25.1  | 33.0       | 30.8 | 36.2  |
| Age, y                               |          |                                 |      |       |                    |      |       |            |      |       |
| 12–13                                | 229      | 28.8                            | 29.7 | 41.5* | 30.1               | 35.8 | 34.1  | 32.3       | 31.9 | 35.8  |
| 14–16                                | 342      | 36.0                            | 35.4 | 28.7  | 35.1               | 30.7 | 34.2  | 34.5       | 33.3 | 32.3  |
| 17–18                                | 193      | 34.2                            | 34.2 | 31.6  | 34.2               | 35.2 | 30.6  | 32.1       | 35.8 | 32.1  |
| SEIFA quintile <sup>2</sup>          |          |                                 |      |       |                    |      |       |            |      |       |
| 1                                    | 129      | 43.4                            | 31.0 | 25.6  | 32.6               | 38.0 | 29.5  | 30.2       | 37.2 | 32.6  |
| 2                                    | 110      | 32.7                            | 26.4 | 40.9  | 35.5               | 25.5 | 39.1  | 32.7       | 36.4 | 30.9  |
| 3                                    | 150      | 32.0                            | 38.0 | 30.0  | 36.0               | 33.3 | 30.7  | 28.0       | 42.7 | 29.3  |
| 4                                    | 149      | 26.9                            | 36.2 | 36.9  | 33.6               | 34.2 | 32.2  | 34.9       | 28.2 | 36.9  |
| 5                                    | 226      | 33.2                            | 33.2 | 33.6  | 31.0               | 34.1 | 35.0  | 37.6       | 27.4 | 35.0  |
| Household equivalent income quintile |          |                                 |      |       |                    |      |       |            |      |       |
| 1                                    | 160      | 32.5                            | 40.0 | 27.5  | 38.8               | 27.5 | 33.8  | 33.1       | 36.3 | 30.6  |
| 2                                    | 135      | 33.3                            | 24.4 | 42.2  | 30.4               | 31.9 | 37.8  | 30.4       | 34.1 | 35.6  |
| 3                                    | 122      | 33.6                            | 33.6 | 32.8  | 35.2               | 41.8 | 23.0  | 27.9       | 35.2 | 36.9  |
| 4                                    | 133      | 39.8                            | 30.8 | 29.3  | 36.8               | 29.3 | 33.8  | 34.6       | 30.8 | 34.6  |
| 5                                    | 129      | 28.7                            | 37.2 | 34.1  | 27.9               | 34.9 | 37.2  | 38.8       | 33.3 | 27.9  |
| Region <sup>3</sup>                  |          |                                 |      |       |                    |      |       |            |      |       |
| Metropolitan <sup>3</sup>            | 407      | 33.9                            | 32.2 | 33.9  | 31.9               | 33.7 | 34.4  | 38.8       | 31.2 | 30.0* |
| Rural and remote <sup>4</sup>        | 250      | 34.4                            | 32.8 | 32.8  | 33.6               | 32.0 | 34.4  | 26.8       | 33.6 | 39.6  |
| Physical activity <sup>5</sup>       |          |                                 |      |       |                    |      |       |            |      |       |
| None/low                             | 195      | 35.9                            | 35.9 | 28.2  | 36.4               | 39.0 | 24.6* | 34.9       | 31.8 | 35.9  |
| Medium/high                          | 205      | 32.2                            | 33.2 | 34.6  | 30.0               | 30.7 | 39.5  | 33.2       | 34.6 | 32.2  |

<sup>1</sup> *n* = 764; values are percentages unless otherwise specified. \*Proportions differed ( $P < 0.05$ ) across thirds of dietary pattern score ( $\chi^2$  statistics).

<sup>2</sup> Tertiles of dietary pattern score are indicated by T1, T2, and T3. Quintile 1 represents areas with a greater number of families of low income and a greater number of people with little training or in unskilled occupations.

<sup>3</sup> Metropolitan areas: Capital city statistical divisions and 1 or more statistical subdivisions that have an urban centre of population 100,000 or more.

<sup>4</sup> Rural and remote areas: Combines rural centers defined as statistical local areas (SLA) containing centers with a population between 10,000 and 99,999, and rural and remote areas defined as SLA containing a center with a population <10,000.

<sup>5</sup> Only subjects aged  $\geq 15$  y were asked questions regarding physical activity.

vegetables pattern ( $\chi^2 = 15.4$ ;  $P < 0.001$ ) and the fruit, salad, cereals, and fish pattern ( $\chi^2 = 9.4$ ;  $P = 0.009$ ) reported consuming breakfast on a greater number of days than did those with low scores, but there was no association with the high fat and sugar pattern.

**Associations of dietary patterns with nutrient intakes and health outcomes.** Adolescents with higher scores on the fruit, salad, cereals, and fish pattern had higher energy-adjusted intakes of protein, fiber,  $\beta$ -carotene equivalents, folate, vitamin C, and potassium and they had lower energy-adjusted intakes of saturated fat (Table 2). Higher scores on the high fat and sugar pattern were associated with higher intakes of energy and higher energy-adjusted intakes of saturated fat, total sugars, and lower energy-adjusted intakes of protein, fiber, folate, iron, and potassium. Higher scores on the vegetables pattern were associated with higher energy-adjusted intakes of protein, polyunsaturated fat, fiber,  $\beta$ -carotene equivalents, folate, vitamin C, calcium, zinc, and potassium.

Because only age, sex, and physical activity were associated with both the dietary patterns and the health outcomes, only these confounders were included in the adjusted models (Table 3). There were no associations between BMI or waist circumference and any of the dietary patterns after adjustment for confounders. Among adolescents aged  $\geq 16$  y ( $n = 282$ ), the fruit, salad, cereals, and fish pattern was significantly associated with diastolic blood pressure ( $P = 0.025$ ), with participants with high scores having lower blood pressure (adjusted for age, sex, and physical activity). There were no significant associations between any of the dietary patterns and systolic blood pressure after adjustment for confounders. Results for blood pressure were similar after further adjustment for BMI and the other dietary patterns (data not shown).

## Discussion

This study sought to identify dietary patterns among a population-based sample of Australian adolescents and whether these were associated with sociodemographic and behavioral variables and with nutrient intakes and health outcomes. Given that there are relatively few studies that have examined these issues in adolescents (17,18,21,25–27), the present findings are important. They demonstrate that dietary patterns of Australian adolescents are associated with various sociodemographic and behavioral characteristics, with nutrient intakes, and that a dietary pattern rich in fruit, salad, cereals, and fish may be associated with lower diastolic blood pressure among adolescents aged  $\geq 16$  y.

It is difficult to compare these findings with earlier studies due to differing study methods. However, the patterns we identified showed some similarities with previous work among children and adolescents. For example, the high fat and sugar pattern was similar to the “snacky” pattern (cakes, biscuits, sweet and salty snacks, and soft drinks) identified by Aranceta et al. (18), the “pizza and drinks” pattern (carbonated drinks, pizza and hamburger, cookies and cakes) identified by Li et al. (20), and the “junk” pattern (crisps, sweets, fried and takeaway foods, soft drinks) from Northstone et al. (23). The fruit, salad, cereals, and fish pattern was also similar to “healthy” patterns identified in children (20,23) and adolescents (17,25).

The finding that none of the dietary patterns in this study were associated with the measures of socioeconomic status is surprising, given the well-established relations in adults (10,52,53). In fact, only 1 study that included adolescents (18) found that a snacky dietary pattern was inversely associated with maternal education, and a 2nd factor, “healthy” (characterized by high intakes of fruits, vegetables, and fish) was inversely associated

**TABLE 2** Energy-adjusted nutrient intakes assessed using the 24-h recall according to tertiles of dietary pattern score among adolescents in the Australian NNS<sup>1,2</sup>

|  | Fruit, salad, cereals, and fish |                  |                  |                      | High fat and sugar |                  |                  |                      | Vegetables       |                    |                   |                      |
|--|---------------------------------|------------------|------------------|----------------------|--------------------|------------------|------------------|----------------------|------------------|--------------------|-------------------|----------------------|
|  | T1                              | T2               | T3               | P-value <sup>4</sup> | T1                 | T2               | T3               | P-value <sup>4</sup> | T1               | T2                 | T3                | P-value <sup>3</sup> |
| Energy, kJ                             | 10,483 $\pm$ 287                | 10,081 $\pm$ 264 | 10,686 $\pm$ 307 | NS                   | 9416 $\pm$ 260     | 10,081 $\pm$ 258 | 11,756 $\pm$ 318 | <0.05                | 10,098 $\pm$ 277 | 10,434 $\pm$ 299   | 10,717 $\pm$ 283  | NS                   |
| Protein, g                             | 88.5 $\pm$ 1.7                  | 89.8 $\pm$ 1.4   | 93.7 $\pm$ 1.9   | <0.05                | 92.4 $\pm$ 1.9     | 91.9 $\pm$ 1.6   | 87.7 $\pm$ 1.6   | <0.05                | 88.2 $\pm$ 1.6   | 90.8 $\pm$ 1.6     | 93.0 $\pm$ 1.9    | <0.05                |
| Total fat, g                           | 94.7 $\pm$ 1.4                  | 93.8 $\pm$ 1.2   | 91.8 $\pm$ 1.3   | NS                   | 91.3 $\pm$ 1.3     | 94.7 $\pm$ 1.3   | 94.3 $\pm$ 1.3   | NS                   | 93.5 $\pm$ 1.3   | 91.3 $\pm$ 1.3     | 95.5 $\pm$ 1.2    | NS                   |
| Saturated fat, g                       | 41.7 $\pm$ 0.8                  | 40.5 $\pm$ 0.7   | 39.2 $\pm$ 0.8   | <0.05                | 39.0 $\pm$ 0.7     | 40.6 $\pm$ 0.7   | 41.8 $\pm$ 0.8   | <0.05                | 40.8 $\pm$ 0.7   | 39.2 $\pm$ 0.8     | 41.4 $\pm$ 0.8    | NS                   |
| MUS fat, <sup>3</sup> g                | 33.3 $\pm$ 0.6                  | 33.3 $\pm$ 0.5   | 32.2 $\pm$ 0.6   | NS                   | 32.4 $\pm$ 0.6     | 33.4 $\pm$ 0.5   | 33.1 $\pm$ 0.6   | NS                   | 33.3 $\pm$ 0.6   | 32.2 $\pm$ 0.6     | 33.3 $\pm$ 0.6    | NS                   |
| Polyunsaturated fat, <sup>2</sup> g    | 12.3 $\pm$ 0.4                  | 12.7 $\pm$ 0.4   | 12.7 $\pm$ 0.4   | NS                   | 12.5 $\pm$ 0.3     | 13.1 $\pm$ 0.4   | 12.1 $\pm$ 0.4   | NS                   | 12.0 $\pm$ 0.4   | 12.5 $\pm$ 0.4     | 13.2 $\pm$ 0.4    | <0.05                |
| Total sugars, g                        | 169.0 $\pm$ 4.6                 | 165.5 $\pm$ 3.6  | 166.9 $\pm$ 4.1  | NS                   | 162.1 $\pm$ 3.7    | 162.7 $\pm$ 4.3  | 176.7 $\pm$ 4.2  | <0.05                | 164.4 $\pm$ 4.2  | 173.8 $\pm$ 4.4    | 163.3 $\pm$ 3.7   | NS                   |
| Carbohydrate, g                        | 322.1 $\pm$ 3.8                 | 321.3 $\pm$ 3.2  | 323.4 $\pm$ 3.6  | NS                   | 323.7 $\pm$ 3.4    | 319.4 $\pm$ 3.6  | 323.8 $\pm$ 3.7  | NS                   | 322.7 $\pm$ 3.4  | 327.1 $\pm$ 3.6    | 317.1 $\pm$ 3.6   | NS                   |
| Dietary fiber, g                       | 19.6 $\pm$ 0.4                  | 21.2 $\pm$ 0.5   | 23.9 $\pm$ 0.6   | <0.05                | 23.9 $\pm$ 0.6     | 20.6 $\pm$ 0.5   | 20.2 $\pm$ 0.5   | <0.05                | 20.4 $\pm$ 0.5   | 21.4 $\pm$ 0.5     | 23.0 $\pm$ 0.6    | <0.05                |
| Vitamin A equivalents, $\mu$ g         | 1274 $\pm$ 241                  | 1197 $\pm$ 165   | 1110 $\pm$ 50    | NS                   | 1045 $\pm$ 42      | 1397 $\pm$ 267   | 1139 $\pm$ 122   | NS                   | 1094 $\pm$ 216   | 1303.5 $\pm$ 197.7 | 1183.1 $\pm$ 47.7 | NS                   |
| $\beta$ -Carotene equivalents, $\mu$ g | 2444 $\pm$ 222                  | 2829 $\pm$ 224   | 3612 $\pm$ 282   | <0.05                | 3086 $\pm$ 226     | 2732 $\pm$ 217   | 3065 $\pm$ 289   | NS                   | 2106 $\pm$ 191   | 3120 $\pm$ 268     | 3655 $\pm$ 261    | <0.05                |
| Folate, $\mu$ g                        | 232.9 $\pm$ 6.1                 | 234.4 $\pm$ 5.2  | 264.7 $\pm$ 6.5  | <0.05                | 263.2 $\pm$ 6.4    | 237.1 $\pm$ 5.4  | 231.6 $\pm$ 6.1  | <0.05                | 227.7 $\pm$ 5.5  | 244.8 $\pm$ 6.1    | 259.4 $\pm$ 6.4   | <0.05                |
| Vitamin C, mg                          | 112.8 $\pm$ 7.5                 | 122.4 $\pm$ 6.7  | 153.8 $\pm$ 8.9  | <0.05                | 142.1 $\pm$ 8.1    | 116.7 $\pm$ 6.9  | 130.1 $\pm$ 8.4  | NS                   | 120.9 $\pm$ 7.9  | 124.7 $\pm$ 7.3    | 143.4 $\pm$ 8.2   | <0.05                |
| Calcium, mg                            | 970.2 $\pm$ 31.0                | 972.9 $\pm$ 28.1 | 983.3 $\pm$ 31.3 | NS                   | 985.5 $\pm$ 30.4   | 986.3 $\pm$ 27.8 | 954.5 $\pm$ 32.1 | NS                   | 932.1 $\pm$ 28.8 | 953.6 $\pm$ 29.4   | 1040.9 $\pm$ 31.8 | <0.05                |
| Iron, mg                               | 13.6 $\pm$ 0.4                  | 14.5 $\pm$ 0.4   | 14.4 $\pm$ 0.3   | NS                   | 15.0 $\pm$ 0.4     | 14.3 $\pm$ 0.4   | 13.2 $\pm$ 0.3   | <0.05                | 13.7 $\pm$ 0.4   | 14.0 $\pm$ 0.3     | 14.7 $\pm$ 0.4    | NS                   |
| Zinc, mg                               | 11.1 $\pm$ 0.3                  | 11.3 $\pm$ 0.3   | 11.5 $\pm$ 0.3   | NS                   | 11.6 $\pm$ 0.3     | 11.2 $\pm$ 0.2   | 11.1 $\pm$ 0.3   | NS                   | 10.9 $\pm$ 0.2   | 11.3 $\pm$ 0.3     | 11.7 $\pm$ 0.3    | <0.05                |
| Potassium, mg                          | 3071 $\pm$ 69                   | 3131 $\pm$ 56    | 3333 $\pm$ 66    | <0.05                | 3350 $\pm$ 60      | 3068 $\pm$ 63    | 3116 $\pm$ 67    | <0.05                | 3013 $\pm$ 56    | 3117 $\pm$ 62      | 3405 $\pm$ 71     | <0.05                |

<sup>1</sup> Values are means  $\pm$  SEM;  $n = 764$ . Significant linear trends ( $P < 0.05$ ) across thirds of dietary pattern score.

<sup>2</sup> Tertiles of dietary pattern score are indicated by T1, T2 and T3.

<sup>3</sup> MUS, monounsaturated.

<sup>4</sup> NS,  $P \geq 0.05$ .

**TABLE 3** Risk factors across tertiles of dietary pattern score adjusted for age, sex, and physical activity<sup>1,2</sup>

| Risk factor                                  | Overall     | Fruit, salad, cereals, and fish |             |             | High fat and sugar |             |             | Vegetables  |             |             |
|--|-------------|---------------------------------|-------------|-------------|--------------------|-------------|-------------|-------------|-------------|-------------|
|  |             | T1                              | T2          | T3          | T1                 | T2          | T3          | T1          | T2          | T3          |
| BMI, kg/m <sup>2</sup>                       | 22.6 ± 0.2  | 22.6 ± 0.4                      | 22.6 ± 0.4  | 22.6 ± 0.4  | 23.3 ± 0.4         | 22.6 ± 0.3  | 22.0 ± 0.4  | 22.7 ± 0.4  | 22.9 ± 0.4  | 22.3 ± 0.4  |
| Waist circumference, cm                      | 75.4 ± 0.5  | 75.1 ± 0.8                      | 75.0 ± 0.8  | 75.7 ± 0.9  | 76.1 ± 0.9         | 74.8 ± 0.8  | 74.9 ± 0.9  | 75.0 ± 0.8  | 76.0 ± 0.8  | 74.7 ± 0.8  |
| Systolic blood pressure, mm Hg <sup>3</sup>  | 116.5 ± 0.7 | 115.5 ± 1.2                     | 118.0 ± 1.1 | 116.1 ± 1.2 | 115.5 ± 1.2        | 115.9 ± 1.1 | 118.5 ± 1.3 | 115.5 ± 1.2 | 116.0 ± 1.2 | 118.2 ± 1.2 |
| Diastolic blood pressure, mm Hg <sup>4</sup> | 66.4 ± 0.6  | 66.5 ± 1.0                      | 68.3 ± 1.0  | 64.3 ± 1.1* | 66.5 ± 1.1         | 65.8 ± 1.0  | 67.1 ± 1.1  | 67.7 ± 1.0  | 66.0 ± 1.0  | 65.6 ± 1.0  |

<sup>1</sup> Values are means ± SE calculated using ANOVA adjusted for age, sex and physical activity. \*Means differed ( $P < 0.05$ ) across thirds of dietary pattern score.

<sup>2</sup> Tertiles of dietary pattern score are indicated by T1, T2, and T3.

<sup>3</sup> Further adjustment for BMI and other dietary patterns did not alter the results.

<sup>4</sup> Blood pressure was collected among adolescents aged ≥16 y,  $n = 282$ .

with maternal education. Conversely, Alexy et al. (17) and Song et al. (26) observed no differences in dietary intake cluster by maternal education level. However, Mikkilä et al. (21) showed that education differences were not apparent at baseline, but they found they did emerge at the 6- and 21-y follow-ups, suggesting socioeconomic gradients in dietary patterns may require time to become entrenched during the life-course. An alternative explanation is the use of different measures of socioeconomic status.

In this study, participants with high scores on the fruit, salad, cereals, and fish pattern had lower diastolic blood pressure. However, it should be noted that this is a cross-sectional study and the relationship was not linear; therefore, it is not possible to say whether this relationship is causal. The only published study to our knowledge investigating dietary patterns and blood pressure in adolescents found no relationship between any of their identified patterns and either systolic or diastolic blood pressure (27). However, the results of the current study are consistent with existing studies of dietary patterns in adults. Among Dutch women, Van Dam et al. (54) identified a dietary pattern characterized by rice, chicken, fish, and vegetables that was inversely associated with blood pressure (54). Also, among British women, a fruit, vegetables, and dairy pattern was inversely associated with blood pressure (55). Similarly, these results are consistent with the results of the Dietary Approaches to Stop Hypertension trial (56), which found that a diet rich in fruits, vegetables, and low-fat dairy products was associated with reduced blood pressure. Dietary patterns associated with lower blood pressure in adults may be similar in children and adolescents and may offer avenues for minimizing increased blood pressure throughout the life-course (57).

Although the results were not significant, the finding that the high consumers of the high fat and sugar pattern had lower BMI is of interest. As this is a cross-sectional study, this finding could be a result of changes in behavior among those with a higher BMI or of dietary under-reporting (58,59). However, due to the lack of energy intake data from the FFQ, we are unable to assess dietary misreporting in this study population. In a review of dietary patterns and obesity in adults, Togo et al. (60) reported a mixed finding among cross-sectional studies with energy-dense food patterns directly associated with obesity in 5 studies and inversely associated in 4 studies. Longitudinal studies are required to further investigate the importance of dietary patterns and obesity in adolescence.

Using nutrient data collected from 24-h recalls, we showed that our dietary patterns reflected intakes of nutrients important for the prevention of chronic disease, including saturated fat, fiber,  $\beta$ -carotene equivalents, folate, vitamin C, and potassium (61). This highlights that the dietary patterns measure underly-

ing differences in nutrient intakes, capture biologically relevant exposures and describe eating behaviors. These associations with nutrient intakes provide an independent measure of the construct validity of these dietary patterns. In addition, dietary patterns were associated with other eating behaviors such as meal frequency and breakfast consumption. A limitation of this analysis is that both the 24-h recall and the FFQ both rely on memory and are therefore susceptible to similar sources of error (62,63).

A potential source of bias in this study is the high proportion of adolescents ( $n = 322$ ; 29.7%) not completing a valid FFQ. However, compared with the adolescents who were included in this study, sex, age, region of residence, socioeconomic status, physical activity levels, or any of the measured health outcomes did not differ (data not shown). In addition, mean nutrient intakes as assessed by the 24-h recall did not differ between the 2 groups.

Another potential limitation of this study is the lack of adjustment of the dietary patterns for energy intake, although the fruit, salad, cereals, and fish pattern and the vegetables pattern were not associated with energy intake when evaluated with data from the 24-h recall. Northstone et al. (64) have shown that energy adjustment of food intake used in dietary patterns derived by factor analysis is not necessary. However, associations between the dietary patterns and the health outcomes were adjusted for age, sex, and physical activity, which are the major determinants of energy intake. Further adjustment of the associations between blood pressure and the dietary patterns for BMI did not alter the results. However, it is possible that there are other confounders that were not measured in this study or that measurement error in the existing confounders could lead to residual confounding that could not be accounted for.

Further limitations of this study include the lack of portion size data on the FFQ and the measurement of physical activity and blood pressure in the subsample of the study population. The FFQ did not quantify intakes in terms of the grams of food consumed by subjects but only the frequency of intake. However, research has shown that the majority of variation in food intakes is captured by frequency of consumption (65).

We chose to retain the majority of food items as they appeared on the FFQ rather than combine food items into a smaller number of food groups. This reduces the subjective decision making as part of the factor analysis procedures, a potential criticism of dietary patterns analysis (47). The importance of incorporating specific foods has been highlighted in the literature (47) and the impact of varying the number of food groups used has been assessed by McCann et al. (46), who compared results using 36 broad food groups and 168 (mostly) single food items

in dietary pattern analysis using factor analysis. They found that although the number and type of dietary patterns did not change, the relationship between the dietary patterns and cancer risk was substantially attenuated when using broad groups, suggesting that greater detail in food groupings is required.

As mentioned previously, comparisons across studies are difficult due to the data-driven approach of dietary pattern analysis. Existing studies of dietary pattern epidemiology have used a variety of dietary assessment methods and statistical techniques. The work in adolescents is still limited, but among adults, substantial similarities in terms of the types of patterns identified and their associations with health outcomes have been identified (11,15,66). A proposed solution is the use of the simplified dietary pattern score, which allows studies to compare dietary patterns directly (49). In this study, we identified high correlation between the conventional dietary pattern score and the simplified approach and this may be useful for future work in adolescents. Difficulties in comparison among studies of adolescents are compounded by the wide range of ages combined in most studies to date, covering children, adolescents, and young adults (17,18,21,27). The strengths of this study are its use of a national population-based sample that includes both FFQ and 24-h recall dietary data, as well as objective data relating to health outcomes.

This study adds to the existing literature by identifying dietary patterns among adolescents, an infrequently studied population group. Specific dietary patterns were associated with socio-demographic and behavioral variables and with nutrient intakes. A dietary pattern high in fruit, salad, cereals, and fish was inversely associated with diastolic blood pressure among adolescents aged  $\geq 16$  y after adjustment for relevant confounders. Further longitudinal research is required to confirm these findings and to investigate the impact of dietary patterns on other cardiovascular disease risk factors among adolescents.

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