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Dietary Fiber and Nutrient Density Are Inversely Associated with the Metabolic Syndrome in US Adolescents

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ABSTRACT

Background There is no consensus as to whether low dietary intakes of saturated fat or cholesterol, or high intakes of dietary fiber are related to a lower prevalence of metabolic syndrome (MetS) in adolescent children.

Objective To determine whether a fiber-rich diet as measured by a fiber index (grams fiber/1,000 kcal) is associated with lower rates of MetS among adolescents vs a diet low in saturated fat or cholesterol as measured by a saturated fat index (grams saturated fat/1,000 kcal) and a cholesterol index (milligrams cholesterol/1,000 kcal), respectively.

Design/participants/setting Cross-sectional analysis of 12- to 19-year-old boys and girls (N=2,128) who participated in the National Health and Nutrition Examination Survey 1999-2002.

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Outcomes and statistical analyses The prevalence of MetS (abnormal values of three or more of the following: waist circumference, blood pressure, fasting serum high-density lipoprotein cholesterol, triglycerides, and glucose) was compared across quintiles of the dietary indexes (fiber index, saturated fat index, and cholesterol index) derived from 24-hour recalls. χ^2 tests determined the prevalence across dietary quintiles, and multivariate logistic regression evaluated the association of the dietary indexes with MetS. Weighted analyses were used controlling for sex, age, ethnicity, and family income. Significance was set at $P \leq 0.05$.

Results The overall prevalence of MetS was 6.4% (n=138). There was a graded inverse association between the fiber index and MetS ($P < 0.001$) with a threefold difference between the lowest and highest quintiles (9.2% vs 3.1%). Each quintile increase in the fiber index was associated with a ~20% decrease in MetS (adjusted odds ratio 0.83, 95% confidence interval 0.68-1.00; $P \leq 0.043$). Neither the saturated fat index ($P = 0.87$) nor the cholesterol index ($P = 0.22$) was significantly associated with MetS.

Conclusions Higher intakes of dietary fiber, but not low intakes of saturated fat or cholesterol are related to the MetS in adolescents. These findings suggest that to reduce the risks for MetS in adolescents, it is more important to emphasize a paradigm that promotes the inclusion of fiber-rich, nutrient-dense, plant-based foods vs what foods to restrict or exclude as is commonly done when the focus is on total fat, cholesterol, or saturated fat intake.

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The constellation of risk factors for cardiovascular disease (CVD) and metabolic dysfunction factors, including elevated abdominal obesity based on waist circumference, blood pressure, blood glucose and triglyceride levels, and lowered high-density lipoprotein (HDL) cholesterol level, has been named metabolic syndrome (MetS) (1). MetS is associated with an increased risk of all-cause mortality, CVD morbidity and mortality including diabetes; and some cancers (2). In parallel with the

increased prevalence of pediatric obesity, recent reports indicate the emergence of MetS during childhood and adolescence (3-6). Data from the US National Health and Nutrition Examination Survey (NHANES) 2001-2006 indicates a prevalence rate of 8.6% in US adolescents 12 to 19 years of age (7). This observation is of great concern to medical and public health communities because MetS tracks from adolescence to adulthood (8-10) and adolescent MetS is associated with a greater risk of MetS, type 2 diabetes, and CVD 25 to 30 years later (10). Thus, the prevention of MetS in adolescents is an important public health and medical goal.

Several factors contribute to the etiology of MetS in adolescence, but proper nutrition and physical activity behaviors are the cornerstones of its prevention and treatment (11,12). Although studies have documented the influence of physical activity on MetS in youth (13), fewer studies have considered the association between dietary behaviors and MetS among adolescents (14-16). Pan and Pratt (17) reported that more desirable scores on the Healthy Eating Index (HEI) and higher fruit intake were both predictive of lower rates of MetS in US adolescents participating in NHANES 1999-2002. However, it is noteworthy that the HEI used is based on the 1992 Food Guide Pyramid and the 1990 Dietary Guidelines for Americans. A limitation of this version of the index is that the scoring does not discriminate between whole grains and processed grains and thus is not a valid predictor of dietary fiber and whole-grain intake. In addition, the HEI focuses on total dietary fat ($\leq 30\%$) and does not discriminate between saturated and unsaturated fats (18-20). Both saturated fat and dietary fiber have been used as indexes to predict CVD risk, including components of MetS in adults aged 18 to 30 years or older (21-24). Overall, these studies on adults indicate that dietary fiber (grams fiber /1,000 kcal), which is a surrogate marker for nutrient density (or the amount of nutrients/1,000 kcal), is a better predictor of a desirable CVD risk factor status than saturated fat (grams saturated fat/1,000 kcal). Although a reduced intake of saturated fat- and cholesterol-containing foods, and an increased consumption of dietary fiber-containing foods are emphasized in recent pediatric nutrition recommendations (25-28), there is no consensus as to whether reducing saturated fat or dietary cholesterol, or increasing dietary fiber is more likely to result in a lower prevalence of MetS in youth. In fact, few studies have specifically examined this issue in the child or adolescent population, which commonly includes the evaluation of 12- to 19-year-olds (7,14,16,17).

The purpose of this study was to compare the relationships between MetS and three dietary indexes, the fiber index (FI) (grams fiber/10,00 kcal) the saturated fat index (SFI) (grams saturated fat/1,000 kcal), and the cholesterol index (CI) (milligrams cholesterol/1,000 kcal). We hypothesized that a high-fiber diet would be associated with lower CVD risk than either diets low in saturated fat, or low in cholesterol among adolescents.

MATERIALS AND METHODS

Data from NHANES 1999-2000 (29), and 2001-2002 (30), conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention were

obtained and used for this cross-sectional analysis. Each survey was a stratified, multistage, national probability sample of the civilian noninstitutionalized population of the United States. It included a household interview of the sample person by a trained interviewer and a health examination in the mobile examination center. The health examination included a physical examination, a dental examination, radiography, anthropometry, a 24-hour dietary recall, and the collection of blood and urine specimens. Survey response rates for mobile examination center examined persons for NHANES 1999-2000 were 78% (29). The NHANES protocol was reviewed and approved by the National Center for Health Statistics Institutional Review Board. Fully informed consent and assent, where applicable, were obtained from all participants before testing.

We chose to evaluate 12- to 19-year-olds due to their increasing prevalence of obesity and MetS, and the paucity of studies evaluating the relationship of diet to MetS in adolescents (7,14,16,17). Inclusion criteria for this cross sectional evaluation included male and female adolescents aged 12 to 19 years. Exclusion criteria included individuals who refused the blood draw, had not fasted for at least 8 hours, did not have a valid 24-hour diet recall, were pregnant, were taking medications to regulate blood glucose (eg, insulin or an oral hypoglycemic agent), or were extreme outliers for one or more variables.

Dietary Methods

Dietary behavior was collected using a 24-hour recall administered by a trained dietary interviewer at the mobile examination center. The dietary recalls collected for the NHANES 1999-2000 and 2001 surveys used a computer-assisted dietary interview that included a four-step multiple pass approach. In 2002, the dietary data were collected with the use of a five-step multiple pass approach with dietary recall methods that are part of the integrated US Department of Agriculture and NHANES protocol of What We Eat in America (30).

For the purpose of this study, three dietary indexes were calculated from the available data: FI (grams dietary fiber/1,000 kcal), SFI (grams saturated fat/1,000 kcal), and CI (milligrams cholesterol/1,000 kcal). Each of the indexes were selected since they reflect key components of nutrition recommendations for cardiovascular health of children (25,26) and have been linked to cardiovascular health or risks in adults (22,23,25,26,28). Specifically, the FI includes total dietary fiber (soluble and insoluble) and is a surrogate marker for plant-based food intake and nutrient density. For example, the intake of dietary fiber-containing foods (eg, fruits, vegetables, whole grains, legumes, nuts, and seeds), are directly related to dietary fiber level as well as nutrients and phytochemicals associated with cardiovascular health. Both dietary fiber and plant-based food intake tend to be inversely associated with multiple CVD risk factors and CVD (22,23,31-33). The SFI and CI were selected due to being a common focal point of dietary counseling recommendations (25,26,28) as well as their association with cardiovascular health (22-24).

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