Food Creatine and DXA-Derived Body Composition in Boys and Girls Aged 8 to 19 Years

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ABSTRACT: Several small-scale trials indicate a positive correlation between dietary creatine intake and fat-free mass in the pediatric population; whether this connection occurs at the population-wide level remains currently unknown. The main purpose of this cross-sectional study was to calculate the amount of creatine consumed through a regular diet among U.S. boys and girls aged 8 to 19 years, and investigate the link between creatine consumption and dual-energy X-ray absorptiometry (DXA)-derived body composition indices in this population. Data were obtained from the National Health and Nutrition Examination Survey 2017-2018 round, with dietary information and whole-body DXA body composition measures extracted for respondents aged 8 to 19 years (1273 participants, 649 boys and 624 girls). Individual values for total grams of creatine consumed per day for each participant were computed using the average amount of creatine (3.88 g/kg) across all creatine-containing foods. The primary exposure was the mean daily intake of creatine; the primary and secondary outcomes comprised lean mass excluding bone mineral content (BMC), and bone mineral density, BMC, lean mass including BMC, fat mass, and percent body fat, respectively. The average intake of creatine across the sample was 0.65 ± 0.72 g/day (95% CI, from 0.61 to 0.69). Creatine positively correlated with lean mass (excluding BMC) and BMC across the whole sample (r = .18 and .20, respectively; P < .001); a significant negative correlation was found between creatine intake and percent body fat (r = –.09; P = .001). The higher intake of creatine was associated with higher lean mass in girls and higher BMC in boys, while taking more creatine corresponded to less body fat for both genders (P < .05). Our findings indicate a significant correlation between dietary creatine and DXA-derived body composition biomarkers in a nationally representative cohort of U.S. youth. These results justify further research of creatine's role in modifying body morphology in the pediatric population, taking into account the age and sex specific traits.

KEYWORDS: Creatine, lean mass, children, adolescents, NHANES, nutrition, body fat

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Introduction

Creatine (2-[carbamimidoyl(methyl)amino]acetic acid; molecular formula $C_4H_9N_3O_2$) is a naturally-occurring metabolite of arginine, glycine, and methionine that is abundant in animal-source foods. This nitrogenous nutraceutical plays a vital role in several metabolic pathways that promote health and well-being in infants, children, and adults.[1,2] Creatine has been traditionally endorsed as a performance-enhancing compound,[3] yet a shred of growing evidence shows that dietary creatine can support muscle growth and bone accretion across various clinical conditions and age-sensitive adult cohorts.[4,5] Still, the link between creatine consumption and body composition in children appears relatively poorly addressed so far. A few small-scale trials within the pediatric population demonstrated a positive association between creatine intake and fat-free mass and bone biology,[6-8] although not all studies confirmed the link.[9] Furthermore, *research in this area omitted to provide any populational evidence about dietary creatine intake and body composition in youth. Therefore, t*he purpose of this cross-sectional study was to calculate the amount of creatine consumed through a regular diet among U.S. boys and girls aged 8 to 19 years, and investigate the possible association between creatine intake and body composition indices in this population.

Materials and Methods

Data for this study were obtained from the National Health and Nutrition Examination Survey (NHANES) 2017-2018 round. A total of 16 211 civilian non-institutionalized male and female individuals aged 0 to 85 years were selected for NHANES 2017-2018 from 30 different survey locations. Of those selected, 9,254 respondents completed the interview, and 8,704 were examined. For this analysis, a set of data was extracted for participants aged 8 to 19 years who provided valid dietary information and body composition measures (see below). The data collection was carried out between January 2017 and December 2018, with informed consent obtained from all participants or parents/guardians. The ethical approval was granted by the U.S. National Center for Health Statistics

Research Ethics Review Board (Protocol #2018-01, and Continuation of Protocol #2011-17). Dietary intake information was obtained from the NHANES 2017-2018 Dietary Data component. Data were collected via a 24-hour dietary recall interview collected in-person in the Mobile Examination Centers (MEC); assisted interviews were conducted with survey participants 6 to 11 years of age. The dietary intake data were used to estimate the types and amounts of foods and beverages consumed during the 24-hour period prior to the interview (midnight to midnight) and calculate intakes of energy, macro and micronutrients, and other food components. Individual values for total grams of creatine consumed per day for each participant were computed as previously described[10]; the primary exposure used in the analyses was the mean daily intake of creatine across the sample.

Body composition data were acquired from NHANES 2017-2018 Examination Data component on whole-body dual-energy X-ray absorptiometry (DXA). DXA scans were administered to survey participants in the NHANES MEC by certified radiology technologists. Whole-body DXA scans were taken with a Hologic QDR-4500A fan-beam densitometer (Hologic, Inc., Bedford, MA). Hologic software version 8.26:a3* was used to administer all scans, and the radiation exposure was <10 μSv. Further details of the DXA examination protocol are documented elsewhere.[11] The primary outcome was lean mass excluding bone mineral content (BMC); secondary outcomes include BMC, bone mineral density, lean mass including BMC, fat mass, and percent body fat. Descriptive statistics were employed to describe the characteristics of the study population. Data series were analyzed by Kolmogorov-Smirnov test for normality of distribution. Independent samples Mann-Whitney *U* test was used to compare dietary creatine intake across gender and age categories. Multiple regression analyses with entering procedures were utilized to evaluate the association between primary exposure (daily creatine intake) and outcome variables (body composition indicators); the regression models were adjusted for a defined set of co-variates, with Model 1 (generation) included gender and body mass index (BMI), and Model 2 (gender) included age category and BMI. Pearson correlation coefficient was used to analyze the relationship between creatine intake and body composition indices across the sample. All data were analyzed using SPSS Statistics for Mac Version 24.0 (IBM, Armonk, NY), with the significance level set at $P < .05$, and all statistical tests were 2-sided.

Results

A total of 1273 participants aged 8 to 19 years (649 boys and 624 girls) *provided valid* individual dietary data and DXA-derived body composition indices. Table 1 displays the basic demographic and dietary characteristics of the study sample. The mean age was 13.3 years, and the average caloric intake was ~2000 kcal/day. The average intake of creatine across the sample was 0.65 ± 0.72 g/day (95% confidence interval [CI], from 0.61 to 0.69). Boys consumed significantly more creatine per day than girls (0.75 ± 0.83 g vs 0.56 ± 0.59 g; $P < .001$), with the mean difference in creatine consumption was 0.19 g/day (95% CI, from 0.11 to 0.27). In addition, daily intake of creatine was significantly lower in school-aged children comparing to adolescents (0.56 ± 0.61 g vs 0.73 ± 0.80 g; $P < .001$); the mean difference was 0.18 g/day (95% CI, from 0.10 to 0.26).

Table 1. General characteristics of the study sample.

VARIABLE	
Participants, n	1273
Gender, %	
Female	49.0
Age (years), mean ± SD	13.3 ± 3.5
Generation (%)	
School-aged children (8-12 years)	44.9
Adolescents (aged 13-19)	55.1
Body measures, mean ± SD	
Weight (kg)	56.6 ± 21.8
Height (cm)	155.7 ± 15.4
Body mass index (kg/m²)	22.6 ± 6.2
Dietary intake, mean ± SD	
Energy (kcal)	2032 ± 935
Protein (g)	71.3 ± 38.9
Creatine (g)	0.65 ± 0.72

A simple (crude) regression analysis revealed a significant relationship between dietary creatine and most body composition outcomes ($P \leqslant .001$), except for fat mass ($P = .065$). Multiple regression analysis for Model 1 (generation) revealed a good resemblance of the model for both school-aged children and adolescents (R^2 .582 and .740, respectively), with a significant relationship existed between the primary outcome (total lean mass excluding BMC) and the combination of independent variables in both groups ($P < .001$). However, dietary creatine provided no contribution to the model in school-aged children ($P = .591$), while creatine significantly contributed to this model in adolescent group (unstandardized $B = 765.8$; $P = .005$). In Model 2 (gender), we found a high resemblance of the model for both boys and girls (R^2 .836 and .797, respectively), and a significant relationship existed between primary outcome and the combination of independent variables in each group ($P < .001$). Dietary creatine provided a significant contribution to the model for girls (unstandardized $B = 767.5$;

Table 2. Multiple regression results of the relationship between dietary creatine and body composition outcomes across the whole sample (Crude), different age groups (Model 1), and gender (Model 2).

VARIABLES	CRUDE MODEL		MODEL 1				MODEL 2			
			SCHOOL-AGED CHILDREN		ADOLESCENTS		BOYS		GIRLS	
	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*
BMC	.179	<.001	.016	.659	.074	.021	.047	.030	.021	.355
Bone mineral density	.169	<.001	.026	.482	.097	.008	.070	.005	.019	.439
Lean mass excluding BMC	.199	<.001	.015	.591	.056	.005	.030	.067	.047	.011
Lean mass including BMC	.199	<.001	.015	.593	.057	.005	.031	.062	.046	.013
Fat mass	.052	.065	−.013	.291	−.030	.007	−.028	.018	−.022	.036
Percent body fat	−.091	.001	−.047	.053	−.080	<.001	−.056	<.001	−.084	<.001

Abbreviation: BMC, bone mineral content.

P = .011), while no significant contribution was found in boys (*P* = .067). Multiple regression results for other body composition outcomes are depicted in Table 2. Besides, dietary creatine positively correlated with lean mass (excluding BMC) and BMC across the whole sample (correlation coefficients .18 and .20, respectively; *P* < .001). A negative correlation was found between dietary creatine and percent body fat (correlation coefficient—.09; *P* = .001).

Discussion

To our knowledge, this is the first populational study that evaluated the link between creatine consumption from a regular diet and biomarkers of body composition in U.S. children and adolescents. We found that dietary creatine was a significant predictor of whole-body DXA-derived body composition outcomes among adolescents while remained non-significant for school-aged children. The higher intake of creatine was associated with higher lean mass in girls and higher BMC in boys, while taking more creatine corresponded to less body fat in both genders. Our study thus corroborated previous findings toward a link between creatine and body composition in the pediatric population, implying that more creatine taken from food relates to more fat-free mass and less fat.

Arguably the first pediatric trial investigating the link between dietary creatine and body morphology dates back to 1981.[6] The authors from the University of Helsinki Children's Hospital supplemented the diet of 7 gyrate atrophy patients with 1.5 g of creatine daily. Although no usual indices of body composition were evaluated in this pilot trial, the size of muscle fibers significantly increased during 1 year of the modified diet, suggesting the possible role of creatine to counteract muscle atrophy seen in this condition. A subsequent trial corroborated favorable effects of creatine for muscle growth in 13 patients with gyrate atrophy (of those, 7 were aged 6-19 years) who were assigned to a creatine-enriched diet for 5 years.[7] The association between dietary creatine and body composition was also evaluated in 12 boys with Duchenne muscular dystrophy (DMD) and 3 with Becker dystrophy.[12] The authors reported that a diet supplemented with creatine (3.0 g/day) improved bone mineral density in patients still independent of a wheelchair at 3-month follow-up. Tarnopolsky et al[8] found that 4-month creatine intake (0.10 g/kg/day) led to an increase in DXA-derived fat-free mass and reduction in bone breakdown among 31 children with DMD. Creatine also attenuated body fat accumulation in children with acute lymphoblastic leukemia during maintenance chemotherapy,[13] and adolescent combat athletes,[14] and increased whole-body lean body mass in cohorts that included adolescent vegetarians,[15] resistance-trained male and female teenagers,[16-18] and young soccer players.[19] Our findings back up a conclusion from above interventional trials about a tie-in linking creatine intake and body composition while extending this line of evidence to the populational level. Taking more creatine from regular food was associated with higher fat-free mass and lower fat mass in both genders; an interaction was significant for all DXA-derived body components among respondents aged 13 years and over. No explanation for this concurrence has been established so far, but it may involve creatine role in energy metabolism, osmoregulation, and protein biosynthesis that could support a substantial cell dynamism in energy-demanding tissues, such as the skeletal muscle and bone[20] while stimulating energy expenditure in fat cells.[21] This perhaps requires a relatively modest increase in dietary creatine as reported in our study, in contrast to experimental dosages used in interventional trials. Still, the optimal amount of creatine for the pediatric population has yet to be determined.

The relationship between creatine consumption and body composition appears to be moderated by age and gender. The variations found here perhaps illustrate heterogeneous responses in different youth populations due to non-identical patterns of food intake and hormonal milieu.[22-24] In addition, we found that the average intake of creatine in our sample was 0.65 g/day, which is a bit higher comparing to the average amounts of food creatine taken reported in a recent study in the adult U.S. population,[10] and lower than mean amounts reported in NHAHES trial with children and adolescents aged 2 to 19 years.[25] This discrepancy perhaps emphasizes different dietary habits in children and adults toward the intake of creatine-based foods, while additional creatine in children and adolescents could contribute to growth and development. A minor variation between studies may also reflect different techniques employed to handle fragmented dietary entries and missing data, and non-identical sample composition and scaling.[26] Nevertheless, the amount of dietary creatine remains under a threshold load of ~1 g/day, which is generally identified as a daily requirement of dietary creatine for an average person,[27] with only 310 participants (24.3%) consumed ⩾1.0 g of creatine per day in our trial. This calls for further research to specify dietary creatine requirements in a growing population, and explore possible health consequences of inadequate creatine intake.

The present study is not without its limitations. First, we employed here a cross-sectional design that prevents any conclusions about a cause and effect between creatine intake and body composition. Second, we computed creatine intake using single-day interviews, which could be susceptible to recall bias, and cannot account for a day-to-day variation.[25] Furthermore, our data provide no measure or estimation of endogenous creatine production, a possible modifying variable that could account for a total daily creatine load (a sum of creatine synthesized de novo along with creatine consumed from a diet).[27] Finally, further studies should control for other dietary components and lifestyle behaviors (eg, calorie and protein intake, physical activity, and exercise) that could modulate the relationship between food creatine and fat, bone, and muscle content of the human body.

Conclusions

In conclusion, the present study results indicate a significant positive correlation between dietary creatine and DXA-derived lean mass and body mineral content, and a negative association linking creatine intake and fat percentage in a nationally representative cohort of U.S. youth. These findings give grounds for further research of creatine's role in modifying body morphology in the pediatric population while accounting for the age- and gender-specific traits.

Author Contributions

Conceptualization, S.M.O.; methodology, D.K., N.T., V.S., and S.M.O.; validation, D.K., N.T., V.S., and S.M.O.; formal analysis, D.K., N.T., V.S., and S.M.O.; investigation, X.X.; resources, S.M.O.; data curation, S.M.O.; writing—original draft preparation, S.M.O.; writing—review and editing, D.K., N.T., V.S., and S.M.O.; supervision, S.M.O.; project administration D.K. and V.S.; funding acquisition, S.M.O. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data described in the manuscript will be made available upon request.

Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki. The ethical approval to conduct the NHANES 2017-2018 was granted by the U.S. National Center for Health Statistics Research Ethics Review Board (Protocol #2018-01 and Continuation of Protocol #2011-17).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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