Children with Early Sexual Maturation Exhibit Changes in Dairy and Soybean Consumption: A 6-Year Nationwide Study

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Research

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Abstract

Background

Early sexual maturation (ESM) is associated with behavioral disorders in adolescence and hormone-related cancers in adulthood. Dietary pattern (DP) has been noticed in association with ESM. However, to our knowledge, no study has shown that association between DP derived from reduced-rank regression (RRR) and ESM, and whether ESM influences tracking dietary habit in children. This study was therefore to examine the prospective association between childhood dietary pattern (DP) and ESM, and whether ESM influenced children's dietary habit during 6 years of pubertal growth.

Methods

This longitudinal study, using the Taiwan Children Health Study cohort, included 2593 peripubertal children aged 11.1 ± 0.3 years in 2011. DPs were derived by factor analysis (FA) and reduced-rank regression (RRR) methods from food frequency questionnaires. ESM was assessed in 2012 at age 12.1 ± 0.3 years. Multivariate logistic regression was used to examine the association between DP scores and ESM (n = 2593). The change in DP scores between 2011 and 2017 was obtained by comparing baseline DP scores with those participants who completed the final assessment (n = 1018).

Results

At baseline, 3 DPs (dairy–soybean, traditional, and vegetarian diet) were identified using FA. Children with FA-derived dairy–soybean diet had a significantly higher risk of ESM (females: odds ratio [OR] = 1.58, 95% confidence interval [CI]: 1.07, 2.32; *P* = 0.02; males: OR = 1.42, 95% CI: 1.08, 1.86; *P* = 0.01) after adjusting for parent education, family income, fat percentage, total energy intake, and screen time. RRR-derived DPs yielded similar associations. Children who experienced ESM exhibited a significantly higher decrease in DP scores of "dairy–soybean diet" than did children without ESM over a 6-year period. Children with ESM were prone to resume "traditional diet" after completing pubertal growth.

Conclusions

Adherence to "dairy–soybean diet" in childhood were associated with ESM; therefore, children undergoing pubertal growth should be advised on appropriate levels of dairy and soybean consumption, even after completion of pubertal growth.

Data Share Statement

Data described in the manuscript, code book, and analytic code will be made available upon request pending either before or after publication for checking through contact with the authors by emails.

Background

Sexual maturation, or puberty encompasses the growth and maturation of the gonads, of the internal sex organs, and of the external genitalia and the development of secondary sexual characteristics [1]. Epidemiological studies have determined the early sexual maturation (ESM) in association with hormone-related cancers [2] and all-cause mortality in later life [3]. Considering the potential factors influencing ESM, dietary modification is of fundamental interest to public health implications [4].

Several studies have reported that ESM is associated with high consumption of fat, animal protein, and red meat during childhood [5, 6]. By contrast, iron, which is a major nutrient in red meat, concentration in plasma was linked to delayed ESM [7]. Although high prepubertal isoflavone intake in childhood delayed puberty onset, the association of fiber [8] and vegetables [5] with ESM remains under debate [4]. Indeed, no individual dietary factor acts alone in modulating pubertal timing [9].

Studies have indicated that dietary pattern (DP), which relates to the synergistic effects of multiple food components, has an effect on ESM [10–12]. Significant associations have been found between ESM and shellfish and processed meat [12] and unhealthy DPs [11] (white meat, snacks, fried food, and soft drinks). Though children were more likely to undergo ESM if they adhered to the "processed meat and refined grain" pattern, they experienced later pubertal development if their DP included mostly "vegetables and lean proteins" [10]. Notably, no significant association was observed between the "whole grain and fat" pattern and ESM [10]. These contrasting findings may be attributed to differences between Eastern and Western DPs, differing study designs, and the variety of statistical methods used to obtain DPs, such as principle component analysis and factor analysis [10–13]. Moreover, none of the aforementioned studies applied reduced-rank regression (RRR) to extract DPs in relation to ESM. RRR has the advantage of incorporating both disease and diet variables into the regression [9].

Tracking dietary habits from childhood to adulthood demonstrated that the eating habits in childhood are not yet stabilized during the process of pubertal growth [14]. The onset of puberty is accompanied by psychophysiological changes that are linked to brain maturation, physical growth, and appetitive motivation [15, 16]. Possibly, the onset of puberty affects their behavior in nutrition intake. Understanding how DPs change during the process of pubertal growth may provide a comprehensive view of tracking dietary habits from childhood to adolescence.

Hence, this study aimed to (1) characterize peripubertal DPs by using exploratory FA and RRR methods at the age of 11 years, (2) explore the association between DP scores and ESM in both sexes, and (3) assess modification in these DP scores over a 6-year period until the end of pubertal growth (from 11 to 17 years of age) in children with and without ESM.

Materials And Methods

Study population

The analysis herein involved the Taiwan Children Health Study (TCHS) cohort. The TCHS is a longitudinal school-based, nationwide, multidisciplinary study with a multipurpose design for investigating atopy disease, adiposity, nutrition intake, and pubertal growth. The present study involved schoolchildren aged 11 years in 2011 who had already received nutrition education regarding the appropriate types and proportions of foods to consume. Thus, the children were able to answer a food frequency questionnaire (FFQ) in 2011 and 2017 (Fig. 1).

Body composition including body weight, fat mass, and body fat percentage were measured using a body composition machine (IOI 353, Jawon Medical, Korea; accuracy: 0.1 kg). Body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (NAGATA, BW-120, Taiwan) at each school. Body mass index (BMI) was calculated as weight (kg) divided by $(height)^2$. We divided family income into 3 groups: below US$1,666 per month, US$1,666–6,666 per month, and over US$6,666 per month (1 US$ = 30 New Taiwan Dollar). Parental level of education was determined by either mother's highest level of education or father's highest level of education.

Measurement of ESM

Puberty outcomes were assessed in 2012, one year after the FFQ assessment. Children self-reported their Tanner-derived composite stage (TDCS) [17], revealing their pubertal stage. The TDCS contains drawings of the 5 stages of secondary sexual characteristics (pubic hair and breast development for girls and pubic hair and genital development for boys). The two sex characteristics were combined and averaged to create a single Tanner score [18]. Furthermore, ESM was defined as a child reaching a certain pubertal stage earlier than the median age for that stage [19], referencing 2 large-scale population-based Chinese studies [20, 21]. We validated the Chinese version of the TDCS, and the consistency between Tanner stages from self-reports and physical inspection by a pediatric endocrinologist was high [22].

DP measurement and analysis

We collected dietary intake information in this study by using an FFQ—a modified version of the Nutrition and Health Survey in Taiwan. The survey included 35 questions on 71 food items, which were categorized into the following 9 food groups: vegetables, fruits, staple foods, eggs, milk, yogurt, cheese, meat and fish (meat, fish, shellfish, and organ meat), and soybean products (soybean milk and tofu). The consumption frequency for each food item was evaluated using a scale from 0 to 7 days per week. If a food item was left blank, intake was set to zero [23]. Each food item in the FFQ was assigned a portion size using appropriate local tableware, such as bowl (200 g) and cup (240 mL), for Taiwanese foods, unless the item was from the fast food group. Daily portion sizes were calculated by multiplying the weekly intake frequency by the number of portions and dividing it by 7. Well-trained staff, including one professional dietitian, provided instructions to the participants, who were asked to complete the FFQ by themselves. Participants could ask our staff questions at any time throughout the sessions.

We employed 2 emperical methods, FA and RRR, to derive DPs from the 9 defined food groups in 2011. FA with principal component estimation, an explorative multivariate statistical technique, was used to extract noncorrelated factors from the 9 food groups (predictors). To minimize the number of indicators that have a high loading on one factor, we used varimax orthogonal rotation. Consequently, 3 factor solutions of eigenvalue > 1 were extracted and examined using break point in the scree plot, and food groups with a factor loading greater than 0.4 were used to interpret the factor. Furthermore, RRR considers both predicting variables and the outcome, which, in this study, were food items and ESM (responses with 0 = non-ESM and 1 = ESM), as previously described [9]. In both techniques, the DP score for each individual was calculated as the sum of portion size of each food item, weighted according to the corresponding factor loading greater than 0.4. Each participant's DP score was then categorized into quartiles in which quartile 4 represented those whose diet adhered most to that particular DP.

Six-year tracking was performed using confirmatory analysis in which all factor loadings were the same ones evaluated at baseline, derived from either FA or RRR. Changes in DP score represent actual differences in food consumption frequencies and portion sizes [24].

Physical activity

Participants were asked to report their physical activity during the preceding 7 days by using the validated Chinese version of the International Physical Activity Questionnaire [25]. To express the intensity of physical activities, the daily metabolic equivalent of task (DMET) was calculated as the sum of total energy expenditure for physical activities per body weight per hour (kcal/kg/hour). Screen time per day was determined by average screen time during the whole week (hours/day).

Statistical analysis

Data are expressed as frequency (%) and mean ± standard deviation for categorical and continuous variables, respectively. The chi-square test and Student's *t* test were used to compare differences among groups. The association between the DP score at age 11 and ESM at age 12 in 2593 children was assessed using logistic regression analysis and expressed as odds ratio (OR) and 95% confidence intervals (CIs). The adjusted model was established using multivariate logistic regression that adjusted for parental education, family income, body fat percentage, total energy intake, and screen time.

Paired Student's *t* tests were used to determine the mean difference of DP score in subgroups between the initial evaluation and after achieving sexual maturation (participants who completed both evaluations = 1018). Statistical power was analyzed considering the effect size measured using Cohen's d parameters: < 0.2 = small effect, 0.2 to 0.8 = medium, and > 0.8 = large [26].

Statistical significance level was set at $P < 0.05$. FA and factor loadings derived from RRR were extracted by using PROC FACTOR and PROC PLS DATA = DIET METHO = RRR, respectively, in SAS version 9.4 (SAS Institute Inc.; Cary, NC, USA). SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) was used for descriptive and analytical statistics.

Results

Characteristics of the population

In total, 2593 children aged 11.1 ± 0.3 years were recruited in 2011 and were followed-up to assess the pubertal outcomes in 2012 (aged 12.1 ± 0.3). After 6 years of follow-up, only 1018 children (aged 17.3 ±

0.5) remained in the cohort and completed the questionnaire, Figure 1. Only minor differences were noted between the basic characteristics of those who completed the follow-up in 2018 and those who did not [Additional file 1].

Table 1 presents the baseline characteristics of study participants. Females had a higher total body fat percentage at baseline than did males. BMI increased significantly between the 2 time points in both sexes, and energy intake decreased in females but not in males. We observed significantly decreased DMET and increased sedentary time during growth development in males. In females, although DMET was not significantly different, we noted increased sedentary time over the 6-year interval. We found meaningful changes in dietary habits in terms of intake proportion for carbohydrate, protein, and fat in females. Similarly, in males, we observed that the intake proportion of carbohydrates decreased, whereas that of fats increased; however, we observed no change in protein proportion, Table 1.

Baseline DPs derived from FA and RRR

FA revealed 3 DPs with the highest eigenvalues, which explained 54.9% of the total variance of food intake from the 9 food groups calculated as portion size. The "dairy– soybean diet" included high factor loadings of milk, yogurt, cheese, and soybean products. The "traditional diet" was highly loaded with staple foods, eggs, and meat and fish. The "vegetarian diet" involved a high intake of vegetables and fruits. RRR-derived DP was characterized by high factor loadings of yogurt, cheese, and soybean milk, Table 2.

Association between baseline DPs, derived from FA and RRR, and ESM

In the FA-derived "dairy–soybean diet", higher DP scores were positively associated with ESM in females and males after controlling for parental education, family income, body fat percentage, total energy intake, and screen time. The RRR-derived dairy–soybean DP yielded a similar association with ESM in females and males, Table 3. Particularly, the upper quartiles of the "dairy–soybean diet" score were positively associated with ESM compared with the lowest quartile in females (quartile 3: OR = 4.58, 95% CI: 1.10, 19.07; $P = 0.03$, quartile 4: OR = 5.64, 95% CI: 1.33, 23.91; $P = 0.02$) in the adjusted models; however, the range of 95% CI was relatively wide. Also, RRR analysis revealed that the highest quartiles of the DP score were independently associated with ESM in females (quartile 4: OR = 3.58, 95% CI: 1.17, 10.93; $P = 0.03$) and males (quartile 3: OR = 1.97, 95% CI: 1.01, 3.87; $P = 0.04$; quartile 4: OR = 2.61, 95% CI: 1.32, 5.17; $P < 0.01$). Notably, in males, a DP score in the higher quartiles of the "vegetarian diet" was associated with ESM relative to reference levels (quartile 2: OR = 2.12, 95% CI: 1.07, 4.17; $P = 0.03$; quartile 4: OR = 2.42, 95% CI: 1.22, 4.80; $P = 0.01$), Figure 2.

Association between DP score changes and ESM

Table 4 lists the mean differences in the score changes of DPs derived from FA and RRR over a 6-year interval. The FA-derived "dairy–soybean diet" DP scores dropped significantly more in children with ESM than in children without ESM in both sexes. For the RRR-derived DP, only males with ESM exhibited a significantly decreased DP score, Table 4.

We observed no differences in the “vegetarian diet” and “traditional diet” DP scores between children with and without ESM, Table 4. However, in general, females and males changed their dietary habits, as evidenced by significantly decreased “vegetarian diet” DP scores and an increasing tendency in “traditional diet” DP scores after achieving sexual maturation [Additional file 2].

Discussion

We investigated for the first time the prospective DPs derived from both FA and RRR in association with ESM. Healthy children who adhered to “dairy–soybean diet” during the peripubertal period were more likely to experience ESM. RRR-derived DP yielded a similar association with ESM. The DP score for the “dairy–soybean diet” in children with ESM decreased significantly more than it did in children without ESM over the 6-year period. In general, children were prone to resume the “traditional diet” and follow the “dairy–soybean diet” and “vegetarian diet” to a lesser extent by the end of puberty. These findings have illustrated the need for appropriate dietary modifications to promote healthy pubertal growth.

The 3 major DPs, the “dairy–soybean diet”, the “vegetarian diet”, and the “traditional diet”, contributed 54.9% of the total variation of the 9 food groups identified using the FFQ. Children with ESM adhered to “dairy–soybean diet”, derived from FA and RRR. This diet, which includes milk, yogurt, and dairy products has been associated with accelerated pubertal development in longitudinal studies [27–29]. Milk and dairy products contain measurable quantities of complex steroid hormones and growth factors, such as estrone and 17beta-estradiol [30], insulin-like growth factor 1 (IGF-1), and IGF-binding protein 3 [31] that act on the hypothalamic–pituitary–gonadal axis to modulate reproductive function [4]. Despite the fact that steroid hormones and IGF-1 levels in cow milk are small relative to endogenous production rates in humans [30, 31], their structures are identical [32]. This might affect breast development [33] and pubertal timing [27] in children with high consumption of milk and dairy products. Notably, on average, 35% of total calcium intake among girls 9–12 years is derived from dairy products [28]. 12-month calcium supplementation in children aged 8–12 years advanced the Age at Peak Height Velocity [34]. Also, a higher consumption of total calcium and milk was associated with a high risk of early menarche [28, 35]. In addition, soy products contain considerable quantities of phytoestrogen, which is hormonally similar to mammalian estrogens and their active metabolites [36]. We found that children with ESM consumed more soy milk, which highly contains the isoflavone genistein [37]. Dietary genistein intake at 1–2 years before the Age at Take-Off had a weak positive association with Age at Take-Off, Age at Peak Height Velocity, and age at pubertal stage 2 for breast development [8]. This weak association might be due to the aforementioned study’s smaller sample size compared with ours (227 vs. 1018). However, other cohort studies have found no association between soy-based products and pubertal timing. This disparity may be due to dissimilar exposure timing (aged less than 3 and 6–8 years) [29, 38]. Meanwhile, the adherence to soymilk intake at age 11 may strongly exert the effects of soymilk-derived isoflavone genistein on ESM in the present study. Thus, the time window of phytoestrogen exposure on sexual maturation merits further investigation.

The "traditional diet" was not associated with ESM in children. Similarly, Chen *et al.* [11] found no association between precocious puberty and "traditional diet" included white meat, seafood, vegetables, fruits, and dairy products. Our "traditional diet" pattern included a high intake of animal protein which has been found not associated with early menarche [39, 40]. Meat consumption was not associated with IGF-1 and IGF-binding protein 3 levels that regulate growth and pubertal development [41, 42].

Dietary tracking is increasingly used to determine the stability of dietary habits in children from childhood to adolescence [24, 43–46]. However, the rationale for understanding of factors that influence children's eating habit is limited [14]. We found that children with ESM exhibited a significantly larger decrease in DP scores for the "dairy–soybean diet" than did children without ESM over a 6-year period with the moderate effect size. This is consistent with that of the GINIplus cohort study [45]. However, Harris *et al.* did not evaluate the puberty onset as an influence of tracking dietary habits [45]. In young adulthood, those who experienced ESM were likely to resume the "traditional diet", which was characterized by meat, fish, eggs, and staple foods. The transition from childhood to adolescence seemingly led to children increasingly to adopt the "traditional diet", which is the principal DP in adulthood, regardless of ESM [Additional file 2]. Harris *et al.* [45] found that males increased their meat intake during puberty; whereas, females shifted to a vegetarian diet that protect them from the risk of breast cancer [47]. However, both sexes exhibited significantly lower adherence to the "vegetarian diet" from childhood to adolescence [Additional file 2], with a significant decrease in carbohydrates proportion in their servings, Table 1. Consistently, the low to moderate tracking of fruits and vegetables was observed from childhood to adulthood [45]. These findings emphasize the importance of encouraging healthy eating habits, which include fruit and vegetable consumption, in young people.

Concerning sex differences, the association between the quartiles of the "dairy–soybean diet" and ESM revealed a significant dose-responsive relationship in females but not in males. This suggests that females are seemingly more vulnerable to the effects of the "dairy–soybean diet" than males. By contrast, males who adhered to "vegetarian diet" at age 11 were more likely to experience ESM. Inconsistent with our findings, DPs characterized by fruit and vegetable consumption during early childhood (at age 3) were associated with a delay in pubertal onset [10]. The fact that children consume more fruits and vegetables high on glycemic index, which have been associated with an increased prevalence of obesity, a critical risk factor of ESM [48, 49]. Hence, further research is required on how the consumption of fruits and vegetables with high glycemic index affect the ESM.

Strengths And Limitations

The strengths of our study include its longitudinal design and nationwide representation of children across Taiwan. This is the first study to elucidate the prospective association between DPs deriving from RRR method [9] and ESM. Our DPs, derived from FA with varimax orthogonal rotation were characterized by non-overlapping food groups in each DP that facilitates the interpretation of the DP score's changes over a 6-year period in association with ESM, which has not been done before. In particular, those associations were controlled by parent education, family income, body fat percentage, physical activity, and total energy intake. These potential factors have been considered to modulate the onset of puberty and dietary habits in children [22, 50–52]. Our analysis of DP score changes between one year before the sexual maturation assessment (aged 11) and early adulthood (aged 17) incorporated the critical period of sexual maturation.

The present study also had some limitations. Recall bias in FFQ dietary assessment is a possibility, particularly in children. Children's dietary habits may be partially affected by their family's food choices. We did not assess the role of micronutrient intake in pubertal development [7]. The follow-up rate was about 39%, limiting the external validity of our results. However, we observed no significant differences in the demographics between those who completed follow-up and those who did not [Additional file 1].

Conclusions

FA- and RRR-derived dairy–soybean DPs, characterized by high factor loadings of milk, yogurt, cheese, and soybean products, were consistently associated with increased risk of ESM in both sexes. A "vegetarian diet" in childhood significantly accelerated ESM in males but not in females, meriting further investigation. The onset of sexual maturation modified the children's dietary habits: we noted a downward trend for the "dairy–soybean diet" pattern and the "vegetarian diet" pattern and an upward trend for the "traditional diet" pattern, implying that healthy dietary habits tend to decrease from childhood to adolescence. Therefore, policies should encourage healthy dietary habits, which include consumption of fruits, vegetables, and milk alternatives, during sexual maturation and until adulthood.

Abbreviations

BMI, body mass index; CI, confidence interval; DMET, daily metabolic equivalent of task; DP, dietary pattern; ESM, early sexual maturation; FA, factor analysis; FFQ, food frequency questionnaire; IGF-1, insulin-like growth factor 1; OR, odds ratio; RRR, reduced-rank regression; TCHS, Taiwan Children Health Study; TDCS, Tanner-derived composite stage

Declarations

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Availability of data and materials

The dataset used and/or analyzed in this study are available from the corresponding

author upon reasonable request.

Authors' contribution

YCC, designed research; JWH, and CY conducted research; NTKN, HYF, and SYH analyzed data; NTKN, and YCC wrote the paper; YCC had primary responsibility for final content. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Informed consent was obtained from both the parents and the children prior to the study. The present study followed the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of National Taiwan University Hospital.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflicts of interest.

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Tables

Table 1 Baseline characteristics of study participants in the TCHS cohort according to gender

	Males			Females		
Characteristics	At age 11 (n = 1299)	At age 17 (n = 518)	*P* value	At age 11 (n = 1294)	At age 17 (n = 500)	*P* value
Age, years	11.1 ± 0.3	17.3 ± 0.3	<0.01*	11.1 ± 0.3	17.3 ± 0.5	<0.01*
Parent education						
High school or below	631 (51.2)	240 (47.1)	0.23	605 (50.3)	222 (45.7)	0.07
College or university	494 (40.1)	216 (42.4)		501 (41.6)	210 (43.2)	
Postgraduate school	108 (8.8)	54 (10.6)		97 (8.1)	54 (11.1)	
Family income (USD/month)						
<1,666	580 (47.0)	229 (44.9)	0.71	546 (45.3)	193 (39.7)	0.11
1,666 to 6,666	440 (35.7)	191 (37.5)		444 (36.9)	198 (40.7)	
> 6,666	213 (17.3)	90 (17.6)		214 (17.8)	95 (19.5)	
BMI, kg/m^2	20.4 ± 4.0	21.8 ± 7.3	< 0.01*	19.8 ± 3.6	20.6 ± 3.0	<0.01*
Body fat percentage (%)	16.2 ± 7.9	-		22.8 ± 6.2[#]	-	-
DMET (kcal/kg/hour)	7.5 ± 5.2	5.2 ± 4.7	0.01*	4.1 ± 4.3	4.1 ± 5.1	0.91
Sedentary time (hours/day)	3.0 ± 2.5	3.4 ± 1.8	< 0.01*	2.5 ± 2.3	3.0 ± 1.9	< 0.01*
Energy intake/day (kcal)	1916.8 ± 845.8	1875.6 ± 245.5	0.42	1771.6 ± 776.8	1630.2 ± 202.9	< 0.01*
Carbohydrate (%)	57.9 ± 3.7	55.7 ± 2.6	< 0.01*	57.9 ± 3.7	55.7 ± 2.6	< 0.01*
Protein (%)	16.3 ± 2.1	16.5 ± 1.3	0.13	15.9 ± 1.6	16.9 ± 1.5	< 0.01*
Fat (%)	25.8 ± 3.2	27.8 ± 2.9	< 0.01*	25.9 ± 2.8	31.2 ± 2.9	< 0.01*
ESM at age 12, yes	324 (24.9)	127 (24.5)	0.85	87 (6.7)	34 (6.8)	0.95

The number of participants did not add up to the total number because of missing data.

*$P < 0.05$, indicates differences in characteristics between children at age 11 and those followed-up at age 17.

# Indicates significant difference in body fat percentage between females and males at baseline.

: DMET, daily metabolic equivalent of task; ESM, early sexual maturation; TCHS, Taiwan Children Health Study; USD, United States Dollar.

Table 2 DPs and their factor loadings in the TCHS cohort 2 (n = 2593) as revealed by FA and RRR methods

	Baseline DPs revealed by FA			Baseline DP revealed by RRR
	Dairy– soybean diet[1]	Traditional diet[2]	Vegetarian diet[3]	
Vegetables	0.00	0.18	**0.83**	0.10
Fruits	0.33	0.04	**0.71**	0.14
Staple foods	0.02	**0.79**	0.10	0.23
Eggs	0.33	**0.59**	−0.07	0.32
Milk	**0.61**	0.09	0.23	0.32
Yogurt	**0.73**	0.05	0.15	**0.43**
Cheese	**0.64**	0.21	−0.12	**0.45**
Meat & fish	0.13	**0.75**	0.22	0.34
Soybean products	**0.62**	0.12	0.15	**0.45**

[1] Greater consumption of dairy and soybean products.

[2] Greater consumption of staple foods, eggs, and meat and fish.

[3] Greater consumption of vegetables, fruits, and fruit juices.

Food groups with a factor loading greater than 0.40 (in boldface) were included in the DP.

Definition of abbreviations: DP, dietary pattern; FA, factor analysis; RRR, reduced-rank regression; TCHS, Taiwan Children Health Study.

Table 3 Association between the DPs score at age 11 and ESM at age 12 in the TCHS cohort 2 according to genders (n = 2593)

Methods	DP score (at age 11)	Males (n = 1299)				Females (n = 1294)			
		Unadjusted model		Adjusted model		Unadjusted model		Adjusted model	
		OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	b (95% CI)	*P* value
FA	Dairy–soybean diet	1.12 (1.01, 1.25)	0.04*	1.42 (1.08, 1.86)	0.01*	1.33 (1.08, 1.63)	<0.01*	1.58 (1.07, 2.32)	0.02*
	Traditional diet	1.03 (0.96, 1.10)	0.46	1.04 (0.85, 1.25)	0.72	0.98 (0.83, 1.15)	0.81	0.79 (0.52, 1.20)	0.27
	Vegetarian diet	1.05 (0.95, 1.15)	0.38	1.16 (0.96, 1.40)	0.12	1.12 (0.94, 1.32)	0.20	1.20 (0.89, 1.63)	0.23
RRR	DP score	1.33 (1.06, 1.67)	0.01*	2.49 (1.34, 4.61)	<0.01*	1.71 (1.08, 2.71)	0.02*	2.69 (1.15, 6.33)	0.02*

Adjusted models were adjusted for parent education, family income, body fat percentage, total energy intake, and screen time.

**P* < 0.05.

Definition of abbreviations: CI, confidence interval; DP, dietary pattern; ESM, early sexual maturation; FA, factor analysis; OR, odds ratio; RRR, reduced-rank regression; TCHS, Taiwan Children Health Study.

Table 4 Comparison of DP scores change across puberty in children with and without ESM according to genders (n=1018)

DPs score changes	Males (n = 518)				Females (n = 500)			
	ESM	Non-ESM	*P* value	Effect size	ESM	Non-ESM	*P* value	Effect size
By FA								
Dairy–soybean diet	−0.70 ± 1.18	−0.47 ± 1.09	0.04*	0.23	−0.87 ± 1.32	−0.36 ± 0.82	<0.01*	0.51
Traditional diet	0.12 ± 2.25	0.09 ± 1.96	0.91	0.008	0.14 ± 1.85	0.04 ± 1.56	0.74	0.02
Vegetarian diet	−0.80 ± 1.40	−0.86 ± 1.39	0.68	0.04	−1.34 ± 1.43	−0.87 ± 1.35	0.07	0.34
By RRR	−1.57 ± 1.14	−1.25 ± 1.14	<0.01*	0.19	−1.45 ± 1.26	−1.29 ± 1.08	0.43	0.57

Data are expressed as mean ± standard deviation.

DP score change was calculated as follows: DP score at age 17 − DP score at age 11

* $P < 0.05$.

Definition of abbreviations: DP, dietary pattern; ESM, early sexual maturation; FA, factor analysis; RRR, reduced-rank regression.

Figures

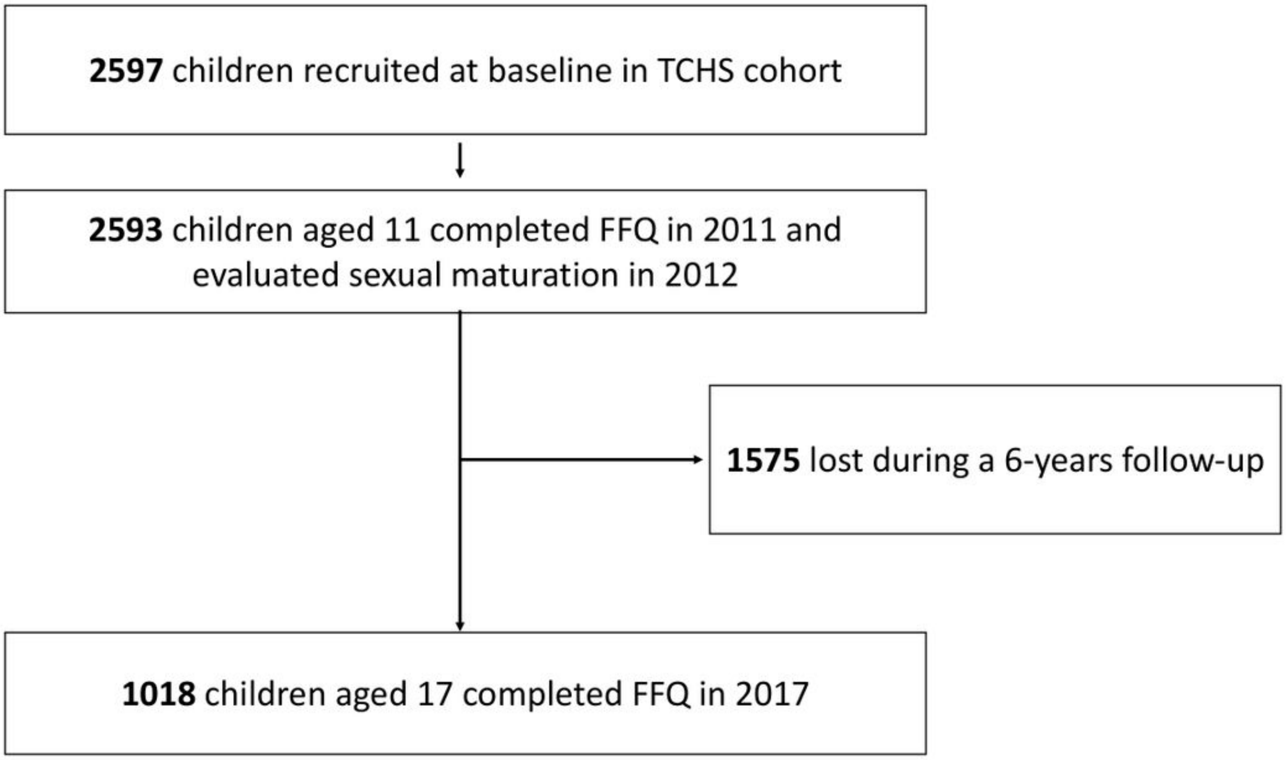

Figure 1

Study flowchart Definition of abbreviations: FFQ, food frequency questionnaire; TCHS, Taiwan Children Health Study.

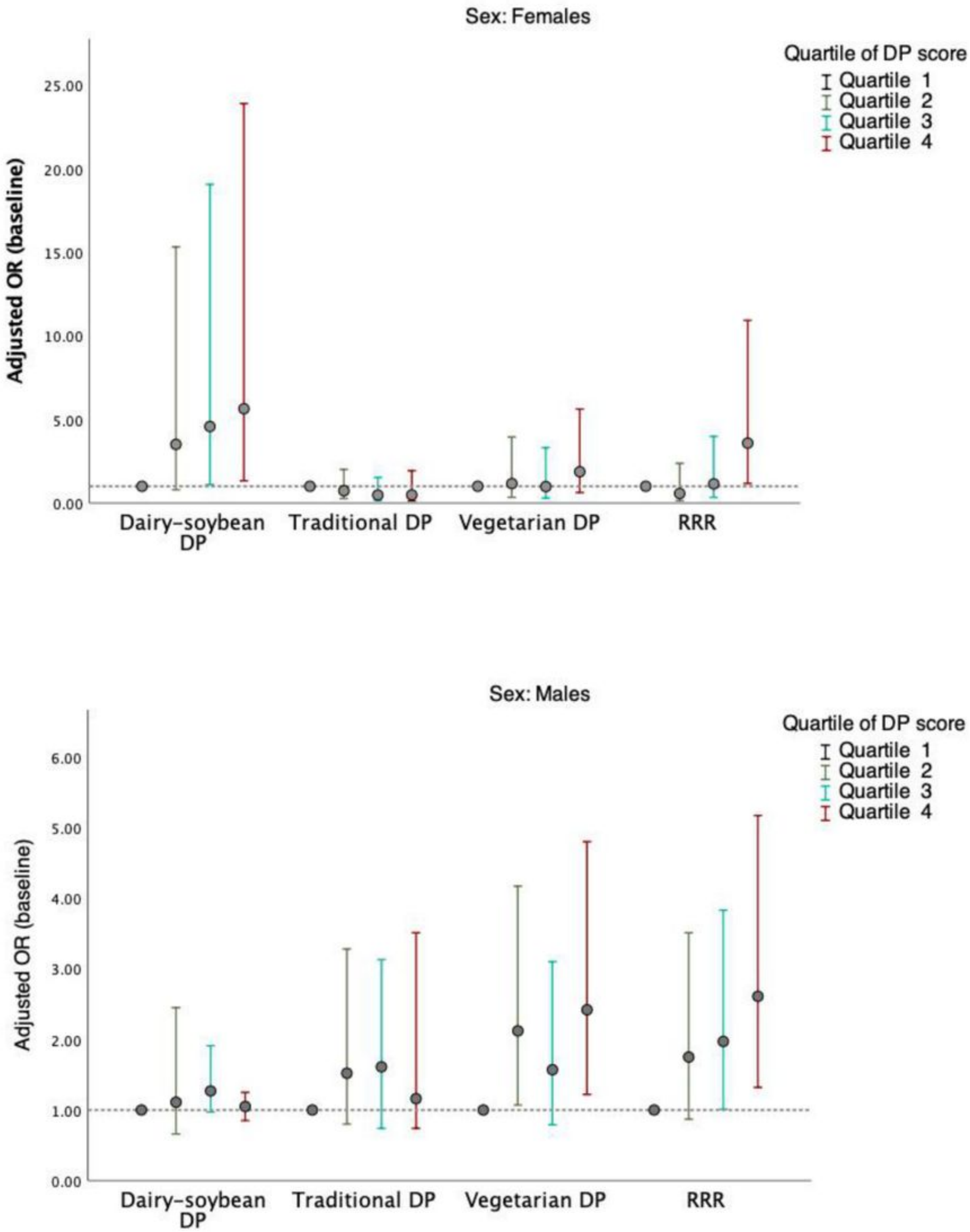

Figure 2

Association between the quartiles of DPs score at age 11 and ESM at age 12 according to genders (n = 2593). Adjusted models were adjusted for parent education, family income, body fat percentage, total energy intake, and screen time. Definition of abbreviations: DP, dietary pattern; ESM, early sexual maturation; OR, odds ratio; RRR, reduced-rank regression; TCHS, Taiwan Children Health Study.

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