Egg Consumption in U.S. Children is Associated with Greater Daily Nutrient Intakes, including Protein, Lutein + Zeaxanthin, Choline, α-Linolenic Acid, and Docosahexanoic Acid

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Abstract: Dietary pattern recommendations include consuming a variety of nutrient-dense foods in children and adolescents to promote optimal growth and development. The current study investigated associations with egg consumption and nutrient intakes, diet quality, and growth outcomes relative to non-egg consumers. The analysis used data from the U.S. National Health and Nutrition Examination Survey (NHANES) 2001-2012 in children and adolescents aged 2–18 years (N = 3,299, egg consumers; N = 17,030, egg non-consumers). Daily energy and nutrient intakes were adjusted for the complex sample design of NHANES using appropriate weights. Consuming eggs was associated with increased daily energy intake relative to non-egg consumption. Children and adolescents consuming eggs had elevated daily intake of protein, polyunsaturated, monounsaturated and total fat, α-linolenic acid, docosahexaenoic acid (DHA), choline, lutein + zeaxanthin, vitamin D, potassium, phosphorus, and selenium. Egg consumers had greater consumption, sodium, saturated fat, with reduced total and added sugar versus egg non-consumers. The analysis also showed that egg consumption was linked with lower intake of dietary folate, iron, and niacin. No associations were determined when examining diet quality and growth-related measures. A sub-analysis considering socioeconomic status showed that egg consumption was positively related with daily lutein + zeaxanthin and DHA intake. The current analysis demonstrated several nutrient-related benefits to support the continued inclusion of eggs in the dietary patterns of children and adolescents.

Keywords: NHANES; children; adolescents; nutrients; eggs; diet quality; dietary patterns

1. Introduction

Since the late 1960s, authoritative bodies have not recommended eggs as part of the diet, largely due to misperceptions resulting from insufficient data that egg consumption contributed to higher cholesterol levels and elevated risk of cardiovascular disease (CVD). In fact, in 1968, the American Heart Association published dietary recommendations to limit consumption of egg yolks to less than three/week [1]. A recent review has argued that this egg-specific dietary guidance was founded on mis-interpreted data that ultimately led to public health nutritional consequences [2]. With several countries removing dietary cholesterol restrictions from dietary guidance and questioning U.S dietary guidance [3–6], the 2015 Dietary Guidelines Advisory Committee (DGAC) [7] report reversed previous recommendations with the statement, “Previously, the Dietary Guidelines for Americans (DGA) recommended that cholesterol intake be limited to no more than 300 mg/day. The 2015 DGAC will not bring forward this recommendation because available evidence shows no appreciable relationship...
between consumption of dietary cholesterol and serum (blood) cholesterol, consistent with the American Heart Association/American College of Cardiology report. Cholesterol is not a nutrient of concern for overconsumption.”

The 2015–2020 DGA policy report [8] emphasizes increased consumption of vegetables, fruits, whole grains, low-fat/fat-free dairy products, and a variety of protein foods, including eggs, seafood, lean meats, legumes, nuts, and soy products. Further, dietary guidance has identified eggs to be nutrient-rich food products when consumed with minimal or no added sugars, sodium and/or solid fats. As such, all healthy dietary patterns recommended by the 2015–2020 DGA include eggs for Americans ≥2 years-old [8]. Nutrient-rich foods, like eggs, can contribute significantly to optimal childhood growth [9]. One 50 g egg (i.e., large egg) provides several essential nutrients and bioactives [10]. Particularly, eggs are an important dietary source of choline, an essential nutrient that is under consumed by the American population [11]. A 50 g egg contributes 146.9 mg of dietary choline and has been documented as a leading food source for choline in the American diet [10,12]. In addition, eggs contain omega-3 fatty acids, such that one large egg contributes about 30 mg docosahexaenoic acid (DHA) and 18 mg octadecatrienoic acid (α-linolenic-acid) [10]. A recent study in American children aged 7 to 12 years reported that few children meet recommendations for omega-3 fatty acids. In particular, only 6.8% of children had adequate intake of DHA + eicosapentaenoic acid (EPA) when using the United Nation Food and Agricultural Organization recommendations, while only 14.1% of children had adequate intakes when using the more lenient recommendations of the National Academy of Medicine [13]. A scientific EFSA panel has acknowledged that children’s brains accrue significant levels of DHA, with emphasis at infancy, but also throughout childhood, thus substantiating a cause and effect link for DHA dietary intake and neural physiology [14]. Eggs also provide highly bioavailable lutein and zeaxanthin, with a 50 g egg contributing approximately 250 mcg lutein + zeaxanthin [10]. Lutein and zeaxanthin are carotenoids which have been linked to eye health and reduced risk for eye- and vision-related diseases [15].

Previously published data in infants demonstrates several beneficial associations with egg consumption, of which included higher recumbent length compared to infants not consuming eggs. Furthermore, introducing eggs during infancy was linked to improved nutrient profiles, including higher daily intakes of protein, DHA, α-linolenic acid, phosphorus, choline, vitamin B12, and lutein + zeaxanthin [16]. At present, there are no studies in children and adolescents that have examined nutrient-related associations between consumers of eggs and non-egg consumers. As such, the purpose of the current investigation was to determine associations between egg consumers, nutrient intakes, diet quality, and growth-related outcomes in Americans 2-18 years of age, in comparison to egg non-consumers.

2. Materials and Methods

The present investigation used data from the US National Health and Nutrition Examination Survey (NHANES), which is a cross-sectional, nationally-representative, sample of U.S. free-living individuals. The data are compiled by the Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia. Written informed consent and all ethical considerations have been previously approved by the appropriate ethics board at the CDC. For the current analysis, the methodology combined 6 datasets for individuals 2–18 years of age, beginning in 2001 and ending in 2012, to provide twelve years of data collection [17]. Data for nutrients are from the U.S. Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS) versions 5.0 and 6.0 for NHANES 2009–2010 and 2011–2012, respectively [18,19]. FNDDS serve as the databases which determine foods and beverages nutrient values in What We Eat in America (WWEIA) [19], which represents the dietary intake component of NHANES. WWEIA considers approximately 150 classifications, 15 central food groupings and 46 food subgroups. The collection procedure for WWEIA involves use of the Automated Multiple Pass Method (AMPM), representing a dietary collection tool that provides a valid, evidence-based approach for gathering data for national dietary surveys [20]. Although two days of
recall are recorded in NHANES, the current analysis focused on 24-hour recalls obtained from Day 1 to represent data collected by an onsite interviewer [20,21]. Accuracy, effectiveness, and efficiency of the AMPM method has been extensively reported and previously documented [22–24].

2.1. Participants and Definition of Eggs

Male and female data on children and adolescents were combined for the present analysis and differentiated as consumers of eggs (N = 3,299) or egg non-consumers (N = 17,030). Only data that was determined to be reliable and included completed 24 hour recalled dietary data was included in the analysis. Egg consumption was defined strictly as participants that consumed only eggs, poached eggs, scrambled eggs, and omelets while excluding egg-containing mixed dishes (i.e., egg-containing sandwiches, breakfast burritos, and all egg-containing bakery foods, including cakes, breads, cookies, and biscuits).

2.2. Methodology

Statistical procedures were completed with the employment of SAS software (Version 9.2, SAS Institute, Cary, NC, USA) and SUDAAN 11.0. The investigation used survey weights to develop nationally representative estimates for children and adolescents, followed by adjustment to consider the complex sample design of the database. Adjusted means (± standard errors) for daily intake of energy (kilocalories), nutrients, and diet quality were determined. Energy, nutrient and diet quality included adjustment for several variables, including age, ethnicity, gender, kilocalories (i.e., all variables with the exception of energy intake), socioeconomic status (i.e., as measured by the poverty income ratio (PIR) and participation in the Special Supplemental Nutrition Program of Women, Infants and Children (WIC)) [24]. Similar adjustments were made for nutrient intakes, body weight, and growth measurements, with the inclusion of an adjustment for energy. USDA’s validated Healthy Eating Index-2010 (HEI 2010) tool was used to measure total diet quality—a measurement of alignment to authoritative dietary guidance [25].

3. Results

3.1. Population Demographics

Study population demographics can be viewed in Table 1. Consumers of eggs and non-egg consumers had differences in age, WIC and PIR status. For PIR, a greater value is representative of a larger income.

Table 1. Mean variables for demographics when comparing egg non-consumers to egg consumers.

| Variable               | Egg Non-Consumers | Egg Consumers | p       |
|------------------------|------------------|---------------|---------|
|                        | Sample N = 17,030| Sample N = 3299|         |
| Age (Years)            | Mean 10.16 SE 0.07 | Mean 9.38 SE 0.17 | < 0.0001 |
| Gender, Male (%)       | 50.76 SE 0.64     | 50.00 SE 1.34 | 0.6088  |
| PIR < 1.35 (%)         | 31.98 SE 1.04     | 39.24 SE 1.78 | 0.0004  |
| 1.35 ≤ PIR ≤ 1.85 (%)  | 11.58 SE 0.56     | 10.19 SE 0.89 | 0.1862  |
| PIR > 1.85 (%)         | 56.44 SE 1.18     | 50.57 SE 1.96 | 0.0103  |
| WIC Participant (%)    | 14.25 SE 0.62     | 18.37 SE 1.13 | 0.0014  |
| Full Food Security (%) | 71.67 SE 0.89     | 68.79 SE 1.57 | 0.1097  |

Mean = least square mean; SE = standard error; PIR = Poverty Income Ratio; WIC = Special Supplemental Nutrition Program of Women, Infants and Children.

3.2. Daily Nutrient and Energy Intakes

Daily nutrient and energy intake comparisons for egg consumers and non-egg consumers can be seen in Table 2. Egg consumption was associated with higher protein, phosphorus, α-linolenic acid),
DHA, polyunsaturated fat, monounsaturated fat, lutein + zeaxanthin, potassium, riboflavin, selenium, choline, vitamins D, A, and E. Egg consumption was associated with significantly lower daily added and total sugar intake. In contrast, consumers of eggs had reduced daily intakes of fiber, folate, and iron. Egg consumption was also linked to greater sodium, saturated and total fat intake compared to non-egg consumers.

Table 2. Day 1 nutrient and energy intakes in egg consumers vs. egg non-consumers.

| Energy/Nutrients                  | Egg Non-Consumers Mean | SE | Egg Consumers Mean | SE | Beta | SE | p     |
|-----------------------------------|------------------------|----|-------------------|----|------|----|-------|
| Energy (kcal)                     | 1959                   | 10 | 2152              | 29 | 194  | 32 | <0.0001|
| Carbohydrate (g)                  | 270.9                  | 0.7| 248.0             | 1.6| −22.8| 1.7| <0.0001|
| Added sugars (tsp eq)             | 21.1                   | 0.2| 18.2              | 0.4| −2.9 | 0.4| <0.0001|
| Total sugars (g)                  | 137.5                  | 0.7| 124.7             | 1.7| −12.8| 1.7| <0.0001|
| Protein (g)                       | 68.4                   | 0.3| 75.5              | 0.7| 7.1  | 0.8| <0.0001|
| Total fat (g)                     | 72.1                   | 0.2| 78.4              | 0.6| 6.3  | 0.7| <0.0001|
| Total MUFA (g)                    | 26.2                   | 0.1| 28.6              | 0.3| 2.4  | 0.3| <0.0001|
| Total PUFA (g)                    | 4.5                    | 0.1| 15.5              | 0.2| 1.0  | 0.2| <0.0001|
| Total SFA (g)                     | 25.4                   | 0.1| 27.3              | 0.3| 1.9  | 0.3| <0.0001|
| PUFA 18:3 (Octadecatrienoic) (g)  | 1.21                   | 0.01| 1.29             | 0.02| 0.08 | 0.02| 0.001 |
| PUFA 20:5 (Eicosapentaenoic) (g) | 0.01                   | 0.0006| 0.02       | 0.001| 0.002| 0.2194|
| PUFA 22:6 (Docosahexaenoic) (g)  | 0.03                   | 0.001| 0.06             | 0.002| 0.035| 0.0001|
| Cholesterol (mg)                  | 176.5                  | 1.0| 494.6            | 6.8| 318.1| 7.1| <0.0001|
| Dietary fiber (g)                 | 13.2                   | 0.1| 12.4             | 0.2| −0.8 | 0.2| <0.0001|
| Calcium (mg)                      | 1022.0                 | 7.4| 997.3            | 15.7| −24.7| 16.7| 0.1426|
| Folate, DFE (µg)                  | 541.2                  | 5.1| 459.6            | 8.1| −81.6| 10.1| <0.0001|
| Iron (mg)                         | 14.5                   | 0.1| 13.6              | 0.2| −0.9 | 0.2| 0.0002 |
| Lutein + zeaxanthin (µg)          | 711.0                  | 18.8| 1035.5           | 49.2| 324.5| 53.6| <0.0001|
| Magnesium (mg)                    | 230.9                  | 1.2| 229.0            | 2.4| −2.0 | 2.5| 0.4269 |
| Niacin (mg)                       | 21.1                   | 0.1| 19.1              | 0.3| −2.1 | 0.3| <0.0001|
| Phosphorus (mg)                   | 1247.7                 | 5.3| 1328.8          | 13.2| 81.1 | 13.4| <0.0001|
| Potassium (mg)                    | 2215.3                 | 13.9| 2274.5          | 24.1| 59.2 | 26.1| 0.0257 |
| Riboflavin (Vitamin B2) (mg)      | 2.07                   | 0.01| 2.19             | 0.03| 0.13 | 0.03| 0.0001|
| Selenium (µg)                     | 89.7                   | 0.4| 110.5            | 1.2| 20.7 | 1.2| <0.0001|
| Sodium (mg)                       | 3102.9                 | 14.0| 3305.3          | 28.2| 202.4| 29.7| <0.0001|
| Thiamin (Vitamin B1) (mg)         | 1.57                   | 0.01| 1.45             | 0.02| −0.12| 0.02| <0.0001|
| Total choline (mg)                | 225.9                  | 1.5| 402.4            | 5.1| 176.4| 5.5| <0.0001|
| Vitamin A, RAE (µg)               | 575.6                  | 6.4| 640.4            | 14.5| 64.8 | 16.0| 0.0001|
| Vitamin B12 (µg)                  | 5.02                   | 0.05| 5.26             | 0.12| 0.24 | 0.14| 0.0951 |
| Vitamin B6 (mg)                   | 1.70                   | 0.01| 1.65             | 0.03| −0.04| 0.03| 0.1583 |
| Vitamin C (mg)                    | 82.4                   | 1.3| 83.3             | 2.0| 0.9  | 2.4| 0.7046|
| Vitamin D (µg)                    | 5.8                    | 0.1| 6.7              | 0.1| 0.9  | 0.1| <0.0001|
| Vitamin E (mg)                    | 5.9                    | 0.1| 6.6              | 0.2| 0.7  | 0.2| 0.0001|
| Zinc (mg)                         | 10.6                   | 0.1| 10.3             | 0.1| −0.4 | 0.1| 0.0079 |

LSMean = least square mean; SE = standard error; Beta = regression coefficient for difference between egg consumers vs. non-egg consumers; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SFA = saturated fatty acids; vitamin D = D2 and D3; vitamin E = as α-tocopherol.

3.3. Diet Quality Scores

The scores for total and sub-categories of Healthy Eating Index-2010 are presented in Table 3. The present analysis did not observe associations between the two egg groups when considering total diet quality, as assessed by HEI-2010. However, associations were apparent in certain sub-categories of HEI-2010. Specifically, consumption of eggs was associated with increased scores for fruits and vegetables, green beans, and total protein foods. Concurrently, egg consumption was also linked to decreased scores for whole grain and sodium consumption, implying that sodium is greater than recommended, and whole grain consumption is lower than recommended.
### Table 3. Day 1 Healthy Eating Index-2010 (HEI) and Sub-Category Mean Scores.

| HEI Total & 12 HEI Sub-Categories          | Egg Non-Consumers | Egg Consumers | p     |
|-------------------------------------------|-------------------|---------------|-------|
|                                            | Mean   | SE    | Mean   | SE    |       |
| Total Vegetables (Category 1)             | 2.08   | 0.02  | 2.18   | 0.05  | 0.0358|
| Greens and Beans (Category 2)             | 0.57   | 0.02  | 0.74   | 0.05  | 0.0034|
| Total Fruit (Category 3)                  | 2.47   | 0.04  | 2.63   | 0.06  | 0.0103|
| Whole Fruit (Category 4)                  | 2.12   | 0.04  | 2.14   | 0.07  | 0.7418|
| Whole Grains (Category 5)                 | 1.94   | 0.04  | 1.65   | 0.09  | 0.0030|
| Total Dairy (Category 6)                  | 7.06   | 0.05  | 6.53   | 0.11  | <0.0001|
| Total Protein Foods (Category 7)          | 3.41   | 0.02  | 4.26   | 0.03  | <0.0001|
| Seafood and Plant Protein (Category 8)    | 1.43   | 0.03  | 1.28   | 0.08  | 0.0473|
| Fatty Acid Ratio (Category 9)             | 3.79   | 0.04  | 3.75   | 0.11  | 0.7088|
| Sodium (Category 10)                      | 5.16   | 0.05  | 4.32   | 0.10  | <0.0001|
| Refined Grains (Category 11)              | 5.18   | 0.05  | 6.00   | 0.11  | <0.0001|
| SOFAAS Calories (Category 12)             | 10.18  | 0.10  | 10.72  | 0.21  | 0.0134|
| **Total**                                 | 45.39  | 0.23  | 46.21  | 0.44  | 0.0656|

Mean = least square mean; SE = standard error; Beta = regression coefficient for difference between egg consumers vs. non-egg consumers; SOFAAS = solid fats, alcohol, added sugars.

#### 3.4. Sub-Analysis to Determine Intake Added Sugar, Carotenoids and Omega-3 Fatty Acids by Socio-Economic Status

In general, consumption of eggs in children and adolescents was linked to reduced daily intake for added sugar, but increased daily intake of lutein + zeaxanthin when compared to non-consumption of eggs in the defined age group. No differences were observed between daily intake of added sugar when subjects were classified as WIC participants. All egg consumers, regardless of their socioeconomic classification, had greater intake of docosahexaenoic acid relative to egg non-consumers. In all cases, except when children were classified as WIC participants, egg consumption was linked to higher α-linolenic acid daily intake when compared to non-egg consumption. In certain socioeconomic groups, but not all, egg consumers exhibited higher eicosapentaenoic acid intake compared to non-egg consumption. All results for added sugar, carotenoid and omega-3 fatty acid intake by socioeconomic status can be seen in Table 4.
Table 4. Day 1 daily Intakes of added sugar, lutein/zeaxanthin, and omega-3 fatty acids by food security, poverty income ratio (PIR) and Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) status.

| Population          | Nutrient                  | Egg Non-Consumers | Egg Consumers | SE | N   | Mean | SE  | N   | Mean | SE  | P     |
|---------------------|---------------------------|------------------|---------------|----|-----|------|-----|-----|------|-----|-------|
| Food Security = High| Added sugars (tsp eq)     | 10,353           | 21.1          | 0.2| 1914| 17.9 | 0.4 | <0.0001 |     |     | |
| Food Security = High| Lutein + zeaxanthin (mcg)| 10,353           | 709.2         | 23.3| 1914| 1073.0| 64.7| <0.0001 |     |     | |
| Food Security = High| PFA 18:3 (Octadecatrienoic) (gm) | 10,352 | 1.20 | 0.01 | 1915 | 1.28 | 0.03 | 0.025 |     |     | |
| Food Security = High| PFA 20:5 (Eicosapentaenoic) (gm) | 10,352 | 0.01 | 0.0008 | 1915 | 0.02 | 0.001 | 0.034 |     |     | |
| Food Security = High| PFA 22:6 (Docosahexaenoic) (gm) | 10,352 | 0.03 | 0.001 | 1915 | 0.06 | 0.003 | <0.0001 |     |     | |
| Food Security = Low | Added sugars (tsp eq)     | 6261             | 21.0          | 0.3 | 1315| 18.9 | 0.6 | 0.0016 |     |     | |
| Food Security = Low | Lutein + zeaxanthin (mcg)| 6261             | 714.9         | 28.0| 1315| 946.6 | 50.8| <0.0001 |     |     | |
| PIR < 1.35          | Added sugars (tsp eq)     | 7079             | 20.3          | 0.3 | 1582| 18.9 | 0.5 | 0.0223 |     |     | |
| PIR < 1.35          | Lutein + zeaxanthin (mcg)| 7079             | 726.3         | 24.9| 1582| 937.4| 47.1| <0.0001 |     |     | |
| PIR < 1.35          | PFA 18:3 (Octadecatrienoic) (gm) | 7079 | 1.23 | 0.01 | 1582| 1.30 | 0.03 | 0.019 |     |     | |
| PIR < 1.35          | PFA 20:5 (Eicosapentaenoic) (gm) | 7079 | 0.02 | 0.001 | 1582| 0.02 | 0.002 | 0.9048 |     |     | |
| PIR < 1.35          | PFA 22:6 (Docosahexaenoic) (gm) | 7079 | 0.03 | 0.002 | 1582| 0.06 | 0.003 | <0.0001 |     |     | |
| PIR ≥ 1.35          | Added sugars (tsp eq)     | 8930             | 21.5          | 0.2 | 1504| 17.7 | 0.5 | <0.0001 |     |     | |
| PIR ≥ 1.35          | Lutein + zeaxanthin (mcg)| 8930             | 703.3         | 23.9| 1504| 1102.8 | 68.8| <0.0001 |     |     | |
| PIR ≥ 1.35          | PFA 18:3 (Octadecatrienoic) (gm) | 8929 | 1.20 | 0.01 | 1505| 1.29 | 0.03 | 0.012 |     |     | |
| PIR ≥ 1.35          | PFA 20:5 (Eicosapentaenoic) (gm) | 8929 | 0.01 | 0.001 | 1505| 0.02 | 0.002 | 0.045 |     |     | |
| PIR ≥ 1.35          | PFA 22:6 (Docosahexaenoic) (gm) | 8929 | 0.03 | 0.001 | 1505| 0.06 | 0.003 | <0.0001 |     |     | |
| WIC Participant = No| Added sugars (tsp eq)     | 10,815           | 21.2          | 0.2 | 1915| 18.1 | 0.5 | <0.0001 |     |     | |
| WIC Participant = No| Lutein + zeaxanthin (mcg)| 10,815           | 719.7         | 22.5| 1915| 1078.6| 67.3| <0.0001 |     |     | |
| WIC Participant = No| PFA 18:3 (Octadecatrienoic) (gm) | 10,814 | 1.22 | 0.01 | 1916| 1.32 | 0.03 | 0.001 |     |     | |
| WIC Participant = No| PFA 20:5 (Eicosapentaenoic) (gm) | 10,814 | 0.01 | 0.001 | 1916| 0.02 | 0.001 | 0.3449 |     |     | |
| WIC Participant = No| PFA 22:6 (Docosahexaenoic) (gm) | 10,814 | 0.03 | 0.001 | 1916| 0.06 | 0.003 | <0.0001 |     |     | |
| WIC Participant = Yes| Added sugars (tsp eq)     | 2832             | 17.6          | 0.3 | 732 | 16.9 | 0.5 | 0.2954 |     |     | |
| WIC Participant = Yes| Lutein + zeaxanthin (mcg)| 2832             | 630.1         | 21.1| 732 | 852.5 | 29.9| <0.0001 |     |     | |
| WIC Participant = Yes| PFA 18:3 (Octadecatrienoic) (gm) | 2832 | 1.17 | 0.03 | 732 | 1.22 | 0.03 | 0.1510 |     |     | |
| WIC Participant = Yes| PFA 20:5 (Eicosapentaenoic) (gm) | 2832 | 0.01 | 0.002 | 732 | 0.01 | 0.002 | 0.2558 |     |     | |
| WIC Participant = Yes| PFA 22:6 (Docosahexaenoic) (gm) | 2832 | 0.02 | 0.002 | 732 | 0.05 | 0.003 | <0.0001 |     |     | |

Mean = least square mean; SE = standard error.
3.5. Weight and Growth Measures

Table 5 provides results for weight and growth outcomes assessed. No significant differences were seen in weight and growth measures examined between egg consumers and egg non-consumers.

Table 5. Adjusted mean (SE) weight and growth measures for egg consumers vs. egg non-consumers.

| Weight/Growth Measures | Egg Non-Consumers | Egg Consumers | p     |
|------------------------|-------------------|---------------|-------|
|                        | N                 | LSMean | SE | N   | LSMean | SE |       |
| Overweight             | 2,771             | 0.14   | 0.01 | 707 | 0.13   | 0.02 | 0.3671 |
| Obese                  | 2,771             | 0.18   | 0.01 | 707 | 0.22   | 0.02 | 0.1270 |
| Overweight or Obese    | 2,771             | 0.32   | 0.01 | 707 | 0.35   | 0.03 | 0.4321 |
| Body Weight (kg)       | 2,806             | 32.5   | 0.3  | 723 | 33.5   | 0.7  | 0.1276 |
| Standing Height (cm)   | 2,769             | 124.8  | 0.2  | 706 | 124.0  | 0.5  | 0.1706 |
| Recumbent Length (cm)  | 2,033             | 96.1   | 0.1  | 602 | 95.6   | 0.3  | 0.2363 |

LSMean = least square mean; SE = standard error; Data were gender combined; NHANES 2001–2012; Day 1 intakes; Covariates include age, gender, ethnicity, poverty income ratio, and energy intake (kcal).

4. Discussion

The current NHANES analysis revealed significant associations with egg consumption in children and adolescents. A dietary pattern that includes eggs was linked with higher amounts of several nutrients, including protein, polyunsaturated and monounsaturated fat, α-linolenic acid, DHA, lutein + zeaxanthin, potassium, phosphorus, choline, riboflavin, selenium, choline, vitamins D, E, and vitamin A. Likewise, egg consumers had lower daily sugar intake (i.e., added and total sugar) when compared to children and adolescents not consuming eggs. Egg consumption was further associated with significantly lower daily intakes of dietary fiber, iron, and folate. The current study also showed that egg consumption was positively related with sodium intake, as well as saturated and total fat intake; thus, preparation of eggs, or foods that accompany eggs may require further investigation. In additional analyses considering socioeconomic status, the current data show benefits linked with egg consumption in this population. In general, egg consumption in children and adolescents, irrespective of food security, poverty and/or WIC status, was related with higher daily intake of lutein + zeaxanthin and DHA, and in most cases, reduced daily intake of added sugar versus the avoidance of eggs in the diet.

The present study further illustrates that choline intake is elevated in children and adolescents consuming eggs. Previous literature has documented the dietary importance of choline, largely due to choline’s relevance in physiology and metabolic activity [9–12] with several publications targeting the critical role choline plays in neuronal structures in early life [9–11]. While data shows that small amounts of choline can be generated endogenously, levels are not sufficient to meet physiological needs [26,27]. Most children consume less than the Adequate Intake (i.e., 550 mg for individuals greater than 4 years of age) [27,28]. A recent NHANES study showed that average choline intake in children and adolescents was approximately 256 mg per day [29]. Eggs have been identified as a leading dietary source of choline—a 50 g hard-boiled egg contributing 146.9 mg total choline or 27% of the recommended Daily Value [10]. As an example, the DGA Healthy Mediterranean-Style eating pattern recommends 5.5 oz equivalents for protein foods (not including dairy foods) within 1600 kcal daily [8]. If allowing for other protein-rich foods, including seafood, meat, poultry, nuts/seeds, etc., and adding two large 50 g eggs (2 oz equivalents) daily to the dietary pattern, a child’s daily choline intake would be approximately 295 mg, representing over 50% of the Adequate Intake for choline [10]. Additionally, since a large egg contributes a good source of dietary DHA [10], consuming 2 eggs daily would represent a DHA intake meeting 24% of EFSA’s daily recommendation for individuals 2-18 years-old (250 mg DHA) [14]. An EFSA expert panel noted a cause and effect mechanism in early brain and nervous system development during infancy and childhood with DHA intake resulting in the approval of claims for food marketing purposes [14].

Our previously published data also verified that consumption of eggs in infants and toddlers was related with increased daily nutrient intake relative to infants consuming no eggs in their dietary
pattern [16]. Indeed, infants consuming egg had significantly higher daily intake of protein, α-linolenic acid, DHA, phosphorus, selenium, choline, lutein + zeaxanthin, and vitamin B12. Infants consuming eggs also had significantly reduced added and total sugar intake compared to non-consumers. However, infant egg consumption was also associated with lowered daily intakes of vitamins D, A, and E, in addition to reduced daily intake of three shortfall nutrients [7,8], including iron, potassium and dietary fiber. This may imply that other food groups, including grain foods, dairy foods, fruits and vegetables, may be key additions to early life eating patterns. Like the current data, the infant/toddler study showed that egg consumption was associated with higher saturated fat and sodium intake. While not investigated in the current study, foods that traditionally accompany eggs, including bacon and sausages, may be contributing to the increased sodium intake in the dietary pattern. This may imply the cooking methods involved with preparing and serving eggs and higher sodium foods that accompany eggs, may require additional scientific evaluation. Further investigation in this area is recommended, particularly with the release of a new report in older adults that showed higher consumption of cholesterol or eggs was associated with a small increase in CVD and all-cause mortality [30]. However, the study did not consider foods often consumed with eggs, including higher added sugar-, saturated fat-, and sodium-containing foods, like bacon, sausages, pancakes, waffles, and syrups.

Also aligned to the infant and toddler data, the current analysis in children and adolescents showed that eggs, as part of a dietary pattern, was not related with HEI, a measure of diet quality. Nevertheless, consumption of eggs in children and adolescents was associated with several HEI sub-categories, of which included, higher values for total fruits and vegetables, beans, and protein foods, but reduced scores for whole grains and total dairy consumption. Sodium scores were reflective of greater sodium intake in children and adolescents consuming eggs, suggesting that preparation of eggs and/or the types of foods that accompany egg meals (i.e., omelets with high-sodium foods including bacon) may need further investigation.

Further, in our current analysis, we did not observe associations with egg or non-egg consumption in several growth outcomes, including overweight, obesity, body weight, standing height or recumbent length. As previously discussed, while protein intake was elevated in children and adolescents consuming eggs, growth and development are multifactorial, thus numerous variables within a dietary pattern can impact such health outcomes [16].

Our analysis involving socioeconomic status revealed associations, such that greater daily lutein + zeaxanthin intake was linked to egg consumption, thus emphasizing the critical dietary role eggs can play with eye health in this population. In most cases, egg consumption was associated with reduced daily intake of added sugar relative to non-egg consumers, suggesting that increased egg consumption in children and adolescents may help to reduce this population’s sodium intake, thus aligning with DGA recommendations. All egg consumers, regardless of their socioeconomic classification, had greater intake of docosahexaenoic acid relative to egg non-consumers. Additionally, except when children were classified as WIC participants, egg consumption was associated with higher intake of α-linolenic acid. Previous work has discussed how diet quality disproportions may potentially be linked to the higher costs of healthier dietary patterns [31], thus, from an economical perspective, eggs may offer nutrient density at a reasonable cost [32].

As has been documented previously in similar research methods [16], the current study has limitations inherent in observational research. NHANES provides a unique tool to researchers in that it offers a large cross-sectional database that pools together sophisticated, in-person interviews with validated physical and biochemical examinations. Limitations include memory recall bias with the 24-hour dietary recall; however, procedures are in place to reduce and minimize error introduction into the dataset. Further strengths and limitations have been previously published and discussed [33–35].

5. Conclusions

This data represents the first study in US children and adolescents to demonstrate nutrient intake associations when comparing egg consumption to non-consumption within a dietary pattern. Egg
intake in this population was associated with increased daily intake of protein, polyunsaturated and monounsaturated fat, α-linolenic acid, DHA, lutein + zeaxanthin, choline, potassium, phosphorus, selenium, riboflavin, vitamins D, A, and E. Likewise, egg consumers had lower daily sugar intake (i.e., added/total sugar) when compared to children and adolescents not consuming eggs. Several shortfall nutrients were associated with egg consumption, including reduced daily intakes of dietary fiber, iron, and folate, concurrently with greater daily intake of sodium, total and saturated fat, suggesting that future research may need to evaluate the contribution of mixed egg meals and the type of foods accompanying eggs in the diet. In additional analyses considering socioeconomic status, the current data show benefits linked with egg consumption in this population. In general, egg consumption in children and adolescents, irrespective of food security, poverty income ratio and/or WIC status, was linked with elevated daily lutein + zeaxanthin and DHA intake, and in most cases, reduced added sugar intake. The present study further illustrates an opportunity to communicate the benefits linked with egg consumption to individuals that influence children and adolescents, including parents, school nutrition organizations, educators, and dietary guideline advisory committees globally.

Author Contributions: V.L.F. and Y.P. were responsible for the intellectual conception and interpretation of the research; V.L.F. generated the design of the research study and completed the final analysis; Y.P. drafted the manuscript, and both Y.P. and V.L.F. provided final editing of the manuscript. Both Y.P. and V.L.F. approved the final draft of the manuscript.

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