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INTAKE OF FREE SUGAR AND MICRONUTRIENT DILUTION IN LEBANESE CHILDREN AND ADOLESCENTS

by
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ABSTRACT
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Lebanon is witnessing the nutrition transition, with its characteristic shifts in diet and lifestyle. One of the hallmarks of the nutrition transition is the increase in sugar intake and the consumption of sweetened processed foods. The population groups that may be the most vulnerable to the ongoing nutrition transition and the concurrent shifts in diet are children and adolescents. Recent studies have suggested that high sugar intake, and particularly free sugars (FS), may be associated with poor dietary quality and micronutrient dilution, the latter being defined as a decrease in micronutrient intakes. The WHO recommended the decrease in FS intake to less than 10% of total energy intake (EI%) and provided another conditional recommendation of further reducing it to <5% EI. While the WHO recommendations aim to prevent dental caries, it remains unknown whether micronutrient intakes would also benefit from these recommendations. This study aims to investigate the association (1) between FS and micronutrient intakes amongst Lebanese children and adolescents and (2) between adherence to the WHO recommended cutoffs and micronutrient intakes.

The study is based on secondary analysis of data stemming from two cross-sectional national surveys conducted among under-five children (survey1) and 5–18-year children and adolescents (survey 2) in Lebanon. In both surveys, data on dietary intake (24-hour recall), socio-demographic and anthropometric characteristics were collected. The Nutritionist Pro software was used for the analysis of dietary intake data and thereafter the calculation of FS intake. For the purpose of this study, six cutoffs of percentages of total energy intake from FS intake (%EFS) were created based on 5% increments: <5% EFS (C1), 5% to <10% EFS (C2), 10% to <15% EFS (C3), 15% to <20% EFS (C4), 20% to <25% EFS (C5), and ≥25% EFS (C6). Absolute micronutrient intakes and micronutrient density (per 1000 kcal) were assessed. Participants' characteristics and mean intake of micronutrients at different FS cutoffs were compared using ANOVA and Pearson Chi square. The odds ratios (OR) of not meeting the nutrient reference values (NRVs) were calculated for each micronutrient using logistic regression models across the 5% increments cutoffs of FS, after adjustment for covariates. Further analyses were conducted in both age groups to calculate the odds of not meeting NRVs across the FS categories that coincided with the WHO recommendations (i.e. <5% EFS compared to >5%; and <10% EFS compared to >10%).

The results showed that 41.4% of the under-fiver children and 59.9% of participants aged 5 to 18 years exceed the WHO recommendation of FS intake (>10% of energy intake). As FS intakes increased, significant decreases were observed in the intakes of most micronutrients, including vitamin D, vitamin A, calcium, iron, folate, and zinc. The absolute intake of micronutrients was observed to be highest when the percent energy intake from FS was between 5% and 10% in both groups, while an excessive intake of FS especially more than 20% energy intake, was associated with significantly lower micronutrient intakes. Nutrient density was also the highest within the <5% EFS (C1) category followed by 5%-10% EFS (C2) in both age groups. The odds of not meeting the respective NRVs increased with increasing FS consumption, especially for participants with intakes falling within 20-25%EFS (C5) and ≥25%EFS (C6). In children aged 6 months to 5 years, participants with FS intake <5% had lower absolute intake of several micronutrients and significant higher odds of not meeting NRVs, a reflection of the lower energy intake in this category. Further logistic regression analyses with adjustment for energy intake showed that participants consuming <5%EFS and <10%EFS had significantly higher odds of meeting the requirements of most nutrients compared to others.

In conclusion, a significant association between FS intake and micronutrient dilution was found in Lebanese children and adolescents. The findings also show that the FS recommendations set by the WHO of <5%EFS or <10%EFS have a positive impact on micronutrient adequacy. This study is the first to provide this evidence among children and adolescents in Lebanon and the Eastern Mediterranean Region in general. Taken together, the results emphasize the need for nutrition education interventions to improve micronutrient intake and diet quality among Lebanese children and adolescents on the short term and decrease NCDs on the long-term.

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ABBREVIATIONS

%	Percent
/	Per
&	and
±	Plus or minus
<	Less than
>	More than
≤	Less than or equal
≥	Greater than or equal
AHA	American Heart Association
AI	Adequate intake
AMDR	Acceptable micronutrient distribution range
BMI	Body mass index
CHO	Carbohydrates
CI	Confidence interval
d	day
DFE	dietary folate equivalent
EAR	Estimated average requirement
EFS	total energy intake from free sugar
EI	energy intake
EMR	Eastern Mediterranean Region
et al.	And others
F	female
FDA	Food and Drug Administration
FS	free sugar
g	gram
HAZ	Height-for-age z score
IOM	Institute of medicine
kg	kilogram

m	month
M	male
mg	milligram
MUFA	Monounsaturated fatty acids
n	Number
N/A	not available
NCDs	Non-communicable diseases
NRVs	nutrient reference values
OR	Odd ratio
P	P value
PUFA	Polyunsaturated fatty acids
RE	Retinol equivalent
SE	Standard error
SPSS	Statistical Package for Social Sciences
SSBs	Sugar sweetened beverages
ug	microgram
UK	United Kingdom
US(A)	United States (of America)
USDA	United States Department of Agriculture
vs.	Versus
WHO	World Health Organization
yrs	years

CHAPTER I

INTRODUCTION

Noncommunicable diseases (NCDs) are the main causes of mortality and morbidity in the world, creating major challenges in developed and developing countries. They lead to 41 million deaths every year, representing 71% of all death globally (UNICEF, 2020). Risk factors of these diseases include unhealthy diets and physical inactivity, which are also common causes of obesity. The latter is rapidly growing globally and is known to be an independent risk factor for several NCDs (Jia et al, 2019). The Eastern Mediterranean region (EMR) is no exception to the global trend in NCDs with available evidence indicating a high burden of NCD-related morbidity and mortality in countries of the region (WHO, 2018).

Like other countries of the EMR, Lebanon is witnessing the nutrition transition, with its characteristic shifts in diet and lifestyle. One of the hallmarks of the nutrition transition is the increase in sugar intake and the consumption of sweetened processed foods (WHO, 2019). The population groups that may be the most vulnerable to the ongoing nutrition transition and the concurrent shifts in diet are children and adolescents. A high intake of sugar, specifically free sugar (FS), has increasingly become an issue of public health concern as it is associated with obesity, poor nutrition and NCDs (WHO, 2019). The term “free sugars” was defined by WHO as “all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates” (WHO, 2015). Recent studies have suggested that high sugar intake, and particularly FS, may be associated with poor dietary quality and micronutrient dilution, the latter being defined as a decrease in micronutrient intakes (Wong, Mok, Ahmad, Rangan, & Louis, 2019). A study conducted amongst children and adolescents in the UK, reported a modest inverse association between micronutrient intake and FS consumption (Gibson, Francis, Kewens & Livingstone, 2016). Similarly, a cross sectional study conducted among Australian children and adolescents indicated a significant dilution effect in most micronutrients with increasing levels of FS consumption (Wong et al, 2019). This is of concern since low micronutrient intake has adverse health effects in the pediatrics population. According to UNICEF (2018), millions of children suffer from cognitive delays, stunted growth, weakened immunity and disease as a result of micronutrient deficiencies. Evidence on the link between FS and micronutrient dilution is scarce in other parts of the world, particularly in countries that are undergoing the nutrition transition, and where the burden of micronutrient deficiencies may be high. A review assessing the nutritional status and dietary intakes of children in Lebanon showed that 35%, 73%-88%, 84%-95% of school aged children did not meet two third of the recommended RDA for iron, calcium, and vitamin D respectively (Nasreddine et al, 2018; DRI, 2005; Salamoun et al, 2005). In addition, the study indicated that 55.3% of these Lebanese children and adolescents did not reach two third the RDA requirements for vitamin A and 23 % to 26% of them did not meet two third the RDA for vitamins E and C.

The WHO recommended the decrease in FS intake to less than 10% of total energy intake (EI%) and provided another conditional recommendation of further reducing it to <5% EI. While the WHO recommendations aim to prevent dental caries, it remains unknown whether micronutrient intakes would also benefit from these recommendations. This study aims to investigate the association between FS and micronutrient intakes amongst Lebanese children and adolescents and 2) between adherence to the WHO recommended cutoffs and micronutrient intakes in this age group.

CHAPTER II

LITERATURE REVIEW

A. Epidemic of NCD worldwide & in the EMR

Noncommunicable diseases (NCDs), also known as chronic diseases, are commonly noninfectious diseases or medical conditions that last for lengthy periods of time and develop slowly (Jia et al, 2019). They include cancer, diabetes, cardiovascular diseases, and respiratory diseases and represent the main causes of mortality and morbidity in the world, creating major challenges in developed and developing countries (UNICEF, 2020). These diseases have become major sources of economic burden to health care systems, leading to 41 million of deaths every year and representing 71% of all death globally (WHO, 2018). Even though NCDs are usually more common in developed countries, they are also of increasing concern in low- and middle-income countries (Jia et al, 2019).

The Eastern Mediterranean region (EMR) is no exception to the global trend in NCDs with available evidence indicating a high burden of NCD-related morbidity and mortality in countries of the region (WHO, 2018). NCDs also place massive pressure on health care systems and resources, leading to major challenges particularly in low- and lower-middle-income areas that constitute more than half of the countries in the EMR. In 2012, NCDs were responsible for more than 2.2 million deaths and were accountable for 57% of mortality in the region (WHO, 2018). In fact, 48% of deaths from chronic diseases in the EMR are attributed to cardiovascular disease, 16% to cancer, 8% to chronic lung diseases, and 5% to diabetes. As for Lebanon, NCDs contribute for nearly 80% of all-cause mortality with cardiovascular disease accounting for 47% (Bassatne et al, 2020). Evidence shows that there will be a further increase in the prevalence of noncommunicable diseases in the EMR that can lead to around 2.4 million deaths in 2025, unless major actions are implemented (WHO, 2018).

B. Risk factors of NCDs

Risk factors for NCDs include non-modifiable risk factors such as age, ethnicity and genetic predisposition, and modifiable factors such as unhealthy diets and physical inactivity (UNICEF, 2020). It has been suggested that suboptimal diets are responsible for more NDC-deaths than any other risk factors worldwide, including tobacco smoking (Afshin et al, 2019). A recent study showed that improvement of diet may potentially prevent one in every five deaths globally, and that unlike many other risk factors, dietary risks can impact individuals' health profile regardless of age, sex, and socio-economic status (Afshin et al, 2019).

In the EMR, studies have also shown that unhealthy diet is the major risk factor for NCD morbidity and mortality (Afshin et al, 2019). The region is in fact witnessing significant changes in its food consumption patterns, mostly characterized by an increase in energy density and the substitution of the traditional diet with a diet high in added sugar, salt, fat and processed items (WHO, 2013). It was indicated that in Jordan, Kuwait, Egypt, Qatar, Iraq, Saudi Arabia, and Syria, around 79 to 96% of adults reported eating less than the recommended five servings of fruit and vegetables per day (WHO, n.d.). Also, evidence shows that salt consumption fluctuates between 7.2 g/day per individual in Lebanon to 19 g/day per individual in Jordan, which is way higher than the recommended intake (WHO, 2013). Another characteristic of the ongoing nutrition transition in the EMR is the rise in added sugar consumption driven by increased intakes of sweetened processed foods and beverages and the decrease in the intake of fruits, vegetables, and milk (Nasreddine et al, 2014; Popkin, Adair & Ng, 2012). A study conducted on university students in UAE showed that 56% of the participants were considered heavy consumers of added sugars and indicated that white sugar was the preferred added sweetener among 90% of the students (Khawaja, Qassim, Hassan, & Arafa, 2019). Another study conducted on female adults in the Saudi Arabia indicated that 81.6% of the participants exceeded the WHO recommended limit of sugar intake, with mean intakes of added sugar expressed as percent of energy intake being estimated at14.1%, 8.63% and 9.86% in underweight, normal weight, and overweight/obese participants, respectively (Mumena et al, 2020).

The intake of added sugar is also particularly high in children and adolescents (Vos et al, 2017). High sugar foods and beverages may increase the risk for overweight, obesity and dental caries among children and adolescents, and may be associated with increased cardiovascular disease, type 2 diabetes mellitus, altered lipid profile and other detrimental health effects (Herrick et al, 2020). They can also cause poor nutrient intake and reduced dietary variety (Fidler et al, 2017). The WHO meta-analysis of 5 prospective cohort studies in children showed that a higher intake of sugar sweetened beverages was associated with a 55% higher risk of becoming overweight or obese compared to those with the lowest intake, after 1-year of follow-up (WHO, 2015). High sugar intakes in childhood and adolescence are of concern given that dietary patterns established early in life tend to track into adulthood, increasing the risk for several diseases later in life (Perrar, Schmittin, Della Crote, Buyken, & Alexy, 2019).

These findings highlight the need to promote and foster healthier dietary habits in children and adolescents. However, it is important to acknowledge that current food systems in the region and worldwide are not necessarily conducive to healthy dietary choices and in most instances, these food systems do not offer nutritious, sustainable, and affordable (Rahman, Hossain, Jahan, 2019). In particular, the food industry may be actually undermining nutrition in many ways, specifically for vulnerable populations. Substantial amounts of money are spent annually on the marketing of foods that are high in sugars, and calories and therefore the consumption of unhealthy diets has increased worldwide, particularly in vulnerable population groups such as children and adolescents who tend to be significantly impacted by food marketing and advertising (Harris & Kalnova, 2018). High sugar foods and beverages are amongst these foods that are heavily marketed, and heavily consumed by this age group (Kearney et al, 2020). This is of concern given that accumulating evidence shows that a high intake of sugar, specifically FS, may be associated with overweight, obesity, poor nutrition, metabolic syndrome, dental caries and NCDs (Jia et al, 2019).

C. Dietary sugars terminologies

The US Federal Drug Administration defines the term "sugar" as a sweet, crystalline substance, $C_{12}H_{22}O_{11}$, obtained chiefly from the juice of sugarcane and sugar beet (Vos et al, 2017). Several definitions of dietary sugar are used in the literature, such as total sugar, free sugar and added sugar. This has become a source of confusion for researchers, policy makers, and consumers and has given rise to discrepant recommendations between countries around the world (Mela & Woolner, 2018). The different sugar terminologies are defined below.

Naturally Occurring Sugars

Naturally occurring sugars include those that represent an innate component of foods, i.e., fructose in fruits and vegetables and lactose in milk and other dairy products (Vos et al, 2017).

Extrinsic and Intrinsic Sugars

The terms extrinsic and intrinsic sugars were proposed by the UK Department of Health. Intrinsic sugars are defined as sugars that are present within the cell walls of plants (naturally occurring sugars) and are always present along with other nutrients (Vos et al, 2017). On the other hand, extrinsic sugars are those not located within the cellular structure of a food and can be found in honey, fruit juice, and syrups and added to processed foods. The term nonmilk extrinsic sugars is used to differentiate lactose-containing extrinsic sugars from all others because the metabolic response for the 2 types of sugars differs significantly (Vos et al, 2017).

Total Sugars

The term *total sugars* refers to all monosaccharides, glucose, fructose and galactose, as well as disaccharides such as sucrose, lactose and maltose, that are present in foods or beverages from any source (Mela & Woolner, 2018). In practice, this mainly includes fructose, sucrose (table sugar), lactose (milk sugar) and glucose (dextrose). The term *sugar* can sometimes refer particularly to sucrose or to all sugars (Mela & Woolner, 2018).

Added Sugars

The term *added sugars* refer to sugars that are not naturally found in the food product and are added during the production of the food (Erickson & Slavin, 2015). The US Dietary Guidelines for Americans (USDA) first defined this term to help consumers in identifying foods and beverages that are high in sugars, and it was used in the scientific literature since then. According to the FDA, added sugar is defined as, "sugars and syrups that are added to foods during processing or preparation" excluding sugars naturally found in foods, such as dairy products or fruits (Erickson & Slavin, 2015). High fructose corn syrup and sucrose are the most frequently added sugars in the food industry (Vos et al, 2017). It is important to note that the definition of added sugars may differ slightly between different other organizations and nutrient databases which results in different estimates and values. For instance, the USDA does not consider fruit juice, in any state, as added sugar, while the FDA suggested, in the Nutrition Facts Label revisions, to consider fruit juice concentrates as added sugars (Food and Drug Administration, 2016). As for the World Health Organization (WHO) sugar recommendations, it uses the term "free sugar" rather than "added sugar". Therefore, without a clear and universal definition, nutrition databases might apply different equations to calculate added sugar leading to a range of different values, that could be confusing to consumers and researchers (Erickson & Slavin, 2015).

Free Sugars

The term "free sugars" was defined by the WHO as "all monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates" (WHO, 2019).

The distinction between added and free sugars is important. All added sugars are also free sugars, and both do not include naturally occurring sugars in intact (fresh, dried, or cooked) fruit and vegetables and in dairy foods (Erickson & Slavin, 2015). The major difference between added and free sugars is that the latter includes all naturally occurring sugars in nonintact (i.e., juiced, or pureed) fruit and vegetables, as well as honey syrups.

D. Current sugar intake guidelines

Throughout the past years, several organizations developed sugar intake guidelines (Table **1**). In 2002, the Institute of Medicine has established an upper limit of added sugars of 25% of total calories (Lupton et al, 2002). The recommendation is based on the concept that foods containing high amounts of added sugars are typically high in calories and low in micronutrients. They did not find any adverse effects related to added sugars below this level, apart from dental caries, but were concerned that micronutrient dilution might occur above 25% of calories from added sugars (Rippe et al, 2017).

In 2005, the Food Guide Pyramid provided Dietary Guidelines for Americans based on food groups for a healthy diet and recommended a range of 6% to 10% of total calorie intake as discretionary calories based on sex, age, and physical activity level of a child (Vos et al, 2017). In fact, discretionary calories refer to the "calories available for consumption as added sugars and solid fats once a child's daily nutrient requirements are met" (Vos et al, 2017). Similarly, the American Heart Association (AHA) reinforced this recommendation in the same year and suggested that "sweetened beverages and naturally sweet beverages, such as fruit juice, should be limited to 4 to 6 ounces per day for children 1 to 6 years old and to 8 to 12 ounces per day for children 7 to 18 years old" (Gidding et al, 2005). As for adults, the

USDA recommends that energy from discretionary foods should not exceed 267 kcal for the average person who needs a daily 2000 kcal diet, to achieve energy balance while satisfying adequate nutrient intake (Cohen et al, 2010).

In 2010, the Dietary Guidelines for Americans suggested that lowering the intake of added sugars can reduce the energy density of the diet without affecting its nutrient content (McGuire, 2011). Actually, the guidelines recommended that sweetened foods and beverages be substituted with those that are low in added sugars or that have no added sugars, such as having water instead of sugary drinks. Moreover, the American Heart Association (AHA) advised in 2010 that adults reduce the consumption of added sugars while meeting their nutritional needs in order to reach and maintain healthy weight and to reduce cardiovascular disease risk (Vos et al, 2017). In the AHA recommendations, added sugars should be limited to 6 teaspoons or 100 calories per day for most American women and 9 teaspoons or 150 calories per day for most American men (Vos et al, 2017).

In 2015, the Dietary Guidelines Advisory Committee published a scientific report suggesting that added sugars should be limited. It highlighted the fact that only a small quantity, specifically 3% to 9% of calories as added sugars are left in a healthy diet after nutrient and food recommendations are met (US Department of Health and Human Services, 2005). Therefore, it was reported that consistent and strong evidence suggests keeping added sugars intake < 10% of total calories intake as it is associated with excess body weight (Vos et al, 2017).

As for the World Health Organization (WHO), it has suggested, since 2003, to limit the intake of FS to less than 10% of total daily energy intake (WHO, 2019). In 2015, the organization developed a guideline on the intake of FS to decrease the risk of noncommunicable diseases in adults and children, specifically focusing on the control and prevention of dental caries, overweight and obesity. The WHO renewed its recommendation the decrease of FS consumption to less than 10% of total energy intake in both adults and children (strong recommendation), and to further reduce the intake of FS to below 5% of total energy intake (conditional recommendation).

Table 1: Suggested recommendations for added or free sugars

YEAR	ORGANIZATION	RECOMMENDATION
2002	Institute of Medicine	Less than 25% of total energy intake from added sugars
2003	World Health Organization	Less than 10% of total energy intake from FS
2009	American Heart Association	No more than half of discretionary calorie intake from added sugars. 150 kcal for males and 100 Kcal for females.
2010	USDA Dietary Guidelines for Americans	5% to 15% of total energy from solid fats and added sugars
2015	World Health Organization	Less than 10% of total energy intake from FS. Also suggests to further reduce FS to less than 5% of total energy intake

E. FDA proposed addition of "added sugar" to food labels

In 2014, the FDA suggested adjustments to the Nutrition Facts and Supplement Facts label in order to support consumers in comparing products, selecting foods that allow them to meet dietary recommendations and thus following a healthy diet (Erickson & Slavin, 2015). The FDA offered several changes, such as adding the category of "Added Sugars" listed below "Sugars" or "Total Sugars". The suggestion from the FDA refers to added sugars as "sugars and syrups added during the food manufacturing process" and considers fruit juice concentrates, not fruit juice, as added sugars (Erickson & Slavin, 2015).

Separating "Added Sugars" from "Total Sugars," the updated Nutrition Fact Label assist the consumers in making healthier choices in their purchases by providing the needed information to differentiate between sugars added by manufacturers and naturally occurring sugars (Food and Drug Administration, 2016). By introducing an "added sugars" category, the FDA expected not to only help consumers in making healthier choices, but to also push food industries to modify their products in order to reduce the quantity of added sugars (Food and Drug Administration, 2016).

F. Sugar consumption in children and adolescents

Today's food environment is characterized by an abundant and cheap sugars supply. Worldwide data show that added sugar consumption starts to increase from the age of 1 year and is highest in school-aged children and adolescents compared to younger children or adults (Newens & Walton, 2016). This appears plausible since sweet preference is higher in childhood and adolescence than in adulthood, making these age groups particularly vulnerable to excessive sugar intakes (Perrar et al, 2019). In the US, added sugars still contribute to nearly 16% of the calories consumed by children daily (Vos et al, 2017). Moreover, around 70% of Americans aged ≥ 2 years exceed the recommendations for added sugars (Codon et al, 2015). In Europe, added sugars were reported to contribute about 14% of daily energy intake in children aged between 2 and 9 years (Poti, Slining, & Popkin, 2013). In Slovenia, mean intake of FS comprised 16% of daily energy intake (130 g/day) in adolescent boys and 17% (110 g/day) in adolescent girls aged 15 to 16 years (Mis, Kobe, & Stimec, 2012). In the UK, soft drinks constituted almost a third of the intake of sugars in children aged 11 to 18 years with biscuits, cakes, puddings, buns, confectionery, and fruit juice being significant contributors as well (SACN, 2015). Another study conducted on adolescents aged 12 to 17 years from 9 European countries reported intakes of 424mL of sugar-containing beverages/day (Rabenberg & Mensink, 2013). Similarly, a German study reported a soft drink intake of 280 mL/day in girls and 480 mL/day in boys aged 12 to 17 years (Linseisen, Gedrich, karg, & Wolfram, 2001). Moreover, a cross-sectional study conducted on 200,000 adolescents aged 11 to 15 years from 43 countries and regions across Europe and North America, indicated that the prevalence of daily soft drink intake increases between ages 11 and 15 years, particularly in boys (Fagt et al, 1008).

A study conducted in Lebanon by Jomaa et. al (2020) showed that high proportions (62%) of children and adolescents exceed the upper limit intake of FS (Jomaa, Hamamji, Kharroubi, Harake, & Nasreddine, 2020). In fact, the food products that contributed to total sugar and FS intake were mainly honey, syrups, sweetened beverages, biscuits and chocolates. The results of the study also showed that Lebanese children with higher household monthly income and paternal educational level had significantly lower chances of high FS intake.

According to the European Society for Pediatric Gastroenterology, Hepatology and Nutrition Position Paper on Complementary Feeding, fruit juices or sugar sweetened beverages should be avoided, and sugars should not be added to complementary foods as well (Fewtrell et al, 2017). However, a study conducted in five European countries showed that these drinks are commonly given to formula fed and breast-fed and infants throughout the first months of life [10]. Moreover, infants given sweetened beverages, juices, tea, or other energy providing liquids showed lower intakes of infant formula and solids (Schiess et al, 2010).

G. Free sugar intakes and micronutrient dilution in children and adolescents

Micronutrient dilution is defined as the decrease in micronutrient intakes that may occur with the increases in FS consumption (Wong, Mok, Ahmad, Rangan, & Louis, 2019). This may be due to the fact that FS increase overall energy intake, and may displace nutrient-dense food, therefore reducing the quality of the diet (Wong et al, 2019). Although the WHO developed a guideline on the intake of FS to decrease the risk of noncommunicable diseases in adults and children, specifically focusing on the control and prevention of dental caries, overweight and obesity, it is not really known whether it could also benefit micronutrient intakes. Also, a study conducted by Lei et al. (2016) that analyzed the data of the Australian Health Survey (AHS) 2011–12, showed that the mean intake of FS was higher among children and adolescents than adults, and that the micronutrient intake of children and adolescents with high FS consumption may be more compromised than amongst adults.

Several studies have investigated the association between added sugar consumption and micronutrient intake (Table **2**). A cross sectional analysis indicated a significant dilution effect in micronutrient intake with increasing FS consumption among Australian children and adolescents and the peak intakes of most micronutrients were found in participants whose FS intake ranged between 0% and 15% of energy (Wong et al, 2019). Analyzed dietary data from the UK National Diet and Nutrition Survey 2008-2012 showed significant negative associations of FS intake with few nutrients, including zinc, iron, copper, vitamin A and vitamin D intakes, among participants aged 11-18 years (Gibson, Francis, Kewens, & Livingstone, 2016). Also, British children and adolescents aged 4-18 years who consumed more than 13% of energy from FS had lower diet quality than the ones who had intakes less than 10% of energy from FS (Gibson et al, 2016). Similarly, a study conducted on 2–18-year-old children and adolescents in Germany identified a slight but significant micronutrient-dilution effect of added sugars as well as a significant decrease in intake of important nutrient- bearing food groups (Alexy, Sichert-Hellert, & Kersting, 2003). In the US, analyzed dietary data from the NHANES 2009-2014 showed significant positive association between added sugars consumption and the percentage of children and adolescents consuming below EAR from calcium, magnesium, and vitamin D (Fulgoni, Gaine, Scott, Ricciuto, & DiFrancesco, 2019). Also, the study observed an intake threshold, whereby added sugars intakes above 19% of energy intake were associated with significant inadequacies in the intakes of magnesium, calcium, and vitamin D. Another study conducted on Irish children and adolescents aged 5-12 years, showed that high intakes of added sugars is associated with a decrease in micronutrient density and an increased prevalence of dietary inadequacies (Joyce & Gibney, 2008), particularly for magnesium, zinc, calcium, vitamin B12 and vitamin C. A study conducted on Norwegian children and adolescents showed a negative association between the intake of added sugars and intakes of micronutrients, fruits, and vegetables (Overby, Lillegaard, Johansson, & Andersen, 2004). Finally, a cross-sectional study conducted on Japanese children and adolescents identified inverse associations between intakes of FS and 21 of 24 micronutrients assessed, except for vitamins A and C and calcium (Fujiwara et al, 2021). Moreover, significantly reduced intakes were observed for 22 and 14 micronutrients in the ≥10% EFS and 5% to <10% EFS categories, respectively, compared with the lower categories.

Micronutrients are important components of a high-quality diet and have a major impact on children and adolescent's health (Mullie et al, 2018). They are responsible for a variety of functions, including enabling the body to produce enzymes, hormones and other substances needed for normal growth and development (WHO, n.d.). The most prevalent micronutrient deficiencies in the pediatric population are vitamin A, vitamin D, iron, zinc and calcium (UNICEF, 2018). According to UNICEF, millions of children suffer from cognitive delays, stunted growth, weakened immunity and disease as a result of micronutrient deficiencies (UNICEF, 2018).

Vitamin A is a nutrient essential for the body's immune system and vision (UNICEF, 2018). A deficiency in this micronutrient weakens the immune system and increases a child's risk of contracting and dying from infections like measles, and diarrheal illnesses (UNICEF, 2018). Vitamin A is also needed for the normal formation and maintenance of the heart, lungs, kidneys, and other organs. Prolonged periods of inadequate vitamin A intake during early childhood can lead to night blindness, anemia, and reduced resistance to infection (World Health Organization, 2009). As for iron, it is essential for growth and development, as well as for the synthesis of red blood cells that carry oxygen through the body (Camaschella, 2019). Iron status is critical in early development given its roles in energy metabolism and the developing of the brain and nervous system (Camaschella, 2019). Infants who experience iron deficiency early in life are at high risk for developmental delays and cognitive deficits, which can persist throughout adulthood (Grantham-McGregor, & Ani, 2001). Moreover, cognitive impairments associated with iron deficiency have been shown to hinder a child's behavior and educational success (Pivina et al, 2019). In addition, iron deficiency also contributes to anemia among children and adolescents (UNICEF, 2018). Zinc plays an important role in growth, cognition, wound healing, and immunity (UNICEF, 2018). A deficiency of this micronutrient in children can lead to growth retardation, hair loss, decreased immunity, loss of appetite, and stunting (Willoughby & Bowen, 2014). An analysis of multiple clinical trials showed that zinc supplementation improved both weight gain and linear growth in children, particularly in children over the age of two years (Liu et al, 2018). Finally, calcium and vitamin D are important for bones and teeth health and their deficiencies can lead to a number of complications in children, including rickets, and poor bone formation that is prone to fractures (Pettifor, 2008). Rickets softens the bones and causes bowlegs, stunted growth, and weak muscles (Pettifor, Thandrayen, & Thacher, 2018).

Country	Study area	Age group	Methods	Results
Australia (Wong et al, 2019)	National	2-18 years	Analyzed dietary data from the Australian Health Survey 2011-12	• Micronutrient intake decreased with increasing percent EFS energy from FS • Peak intakes of most micronutrients were observed between 0% and 15% of EFS • Absolute intakes of most micronutrients were not significantly different between participants who consumed <10%EFS and ≥ 10%EFS • Those with ≥20%EFS were less likely to meet the nutrients reference values of more than half of the micronutrients • Meeting the WHO cutoff was associated with modest improvement in micronutrient adequacy.
UK (Gibson et al, 2016)	National	1.5-18 years	Analyzed dietary data from the UK National Diet and Nutrition Survey 2008-2012	• Significant associations between FS intake and few micronutrients • Among 11–18-year-old participants, there was significant negative associations with Zn, Se, Fe, Cu and vitamin A and D, and positive association with vitamin C. • Children aged 4–18 years who consumed average amounts of FS or above (>13 % energy) had lower micronutrient intake than those consuming <10 % FS
Germany (Alexy et al, 2003)	Dortmund city	2-18 years	Analyzed dietary data from the Dortmund Nutritional and Anthropometric Longitudinally Designed study	• Intakes of all analyzed nutrients significantly decreased across quintiles 1-5 of energy intake from added sugars • Slight but significant nutrient-dilution effect of added sugars and a significant reduction in intake of important nutrient-bearing food groups
Ireland (Joyce &Gibney, 2008)	National	5-12 years	Analyzed dietary data from the National Children's Food Survey and National Teen food Survey	• High consumption of added sugars was associated with a decrease in micronutrient density and increased prevalence of dietary inadequacies • Significant decrease in micronutrient including Mg, Ca, Zn, vitamin B12 and vitamin C.
US (Fulgoni et al, 2019)	National	2-18 years	Analyzed dietary data from NHANES 2009-2014	• Significant positive associations between added sugars intake and percentage of the population below the EAR were found only for Ca, Mg and vitamin D • As added sugars intake increased, a threshold above which an increase in the prevalence of inadequate intakes for Ca, Mg and vitamin D was observed
Norway (Overby et al, 2004)	National	4,9 and 13 years	Analyzed dietary data from the Dutch National Food Consumption Survey 2007-2010	• Negative association between the intake of added sugars and intakes of micronutrients, fruits and vegetables

Japan (Fujiwara et al, 2021)	National	1-19 years	Analyzed dietary data from the Japanese National Health and Nutrition Survey 2016	• Inverse associations were observed between intakes of free sugars and 21 of 24 micronutrients assessed, except for vitamins A and C and calcium. • Significantly reduced intakes were identified for 22 and 14 micronutrients in the ≥10% EFS and 5 to <10% EFS categories, respectively, compared with the lower categories • Free sugars intake had positive associations with intakes of sugars and jams, confectioneries, fruit and vegetable juices, and soft drinks and negative associations with intakes of pulses and nuts and vegetables. • Nutrient dilution was associated with higher free sugars intake among Japanese children and adolescents. • The findings suggest that the WHO recommendations might help prevent nutrient dilution in Japanese children and adolescents.

Table 2: Studies that investigated the association between added or free sugar and micronutrient intake among children and adolescents in different countries

H. Micronutrient intakes amongst children and adolescents in the EMR

A review assessing the nutritional status and dietary intakes of children in the Eastern Mediterranean region identified a triple burden of malnutrition in this age group- underweight, overweight/obesity and micronutrient inadequacies (Nasreddine, Kassis, Ayoub, Naja, & Hwalla, 2018).

In Lebanon, 35%, 73%-88%, 84%-95% of school aged children did not meet two third of the recommended RDA for iron, calcium, and vitamin D respectively (Nasreddine et al, 2018; DRI, 2005; Salamoun et al, 2005). Moreover, a study showed that 77% of 6–19-year-old Lebanese children and adolescents do not meet two thirds of the RDA for calcium (Nasreddine et al, 2020). It also showed that 36% and 27% of this age group do not meet two third the RDA for iron and zinc respectively. In addition, the study indicated that 55.3% of these Lebanese children and adolescents did not reach two third the RDA requirements for vitamin A and 23 % to 26% of them did not meet two third the RDA for vitamins E and C.

A study conducted in Jordan on 5- to 6-year-old children, showed inadequate micronutrient intakes among this age group (Al-Rewashdeh, 2009). In fact, there was an observed deficit in the diet of -33% for seven vitamins including vitamin A, C, thiamin, riboflavin, niacin, folate and B12, as well as -36% deficit for the following four minerals: calcium, iron, zinc and iodine. As for Egypt, almost a third of the children aged 6-12 years did not meet 50% of the RDA for calcium and iron, while 44-76% of them did not meet 50% of the RDA for vitamin A (El-Ghazzar et al, 2019). As in KSA, 63% of 9- to 18-year-old adolescents did not reach the estimated average requirement for vitamin A, while 87% of this age group did not also meet the estimated average requirement for vitamin E (Al-Musharaf et al, 2012). Similarly, evidence showed that more than 80% of children aged 6 to 13 years in the UAE did not reach the respective estimated average requirement (EAR) level for calcium, vitamin D, vitamin A, vitamin E (Nasreddine et al, 2018). Moreover, around 50% of the UAE children aged 9 to 13 years did not meet the recommended EAR levels of magnesium, folate, zinc, and phosphorous (FAO, n.d.; Ali et al, 2013).

Similarly, a review on food consumption patterns of children and adolescents in the EMR showed suboptimal intakes for micronutrients in Iran, Pakistan, Palestine, and the UAE among adolescents (Al-Jawaldeh, Taktouk, & Nasreddine, 2020). It also showed that high proportions of adolescents in Iran, Palestine, Pakistan and KSA did not meet the recommended intake levels of iron, calcium, and zinc. Additionally, the review indicated that several studies in the EMR observed a number of micronutrient inadequacies, specifically low consumptions of vitamins A, D, C and folate as well as iron, calcium and zinc. Also, the review highlighted an observed high intake of sodium coupled with a decrease in potassium intakes among children and adolescents in the EMR, which is a risk factor for an increase in blood pressure during childhood and adolescence that may increase the chances for cardiovascular disease and hypertension later in their life.

Current evidence therefore shows that the intakes of micronutrients amongst children and adolescents are inadequate in countries of the region. Little is known on whether low micronutrients intakes are associated with high sugar intake in this age group. The investigation of this association is crucial as its findings may feed into the development of interventions and policies aimed at reducing sugar intake in the age group.

CHAPTER III

MATERIALS & METHODS

A. Study design:

This study is based on secondary analysis of data stemming from two national cross-sectional surveys conducted in Lebanon on children aged 0 to 5 years (survey 1) and children and adolescents aged 4 to 18 years (survey 2).

B. Study Setting and Data Sources:

This study is based on data collected by two national surveys conducted in the six governorates in Lebanon. The first survey, “Early Life Nutrition and Health” (ELNAHL), was carried out in 2011-2012 and involved a representative sample of Lebanese children aged 0 to 5 years (Nasreddine, Hwalla, Saliba, Akl, & Naja, 2017; Nasreddine et al, 2019). Its goal was to assess the feeding and dietary practices and evaluate the prevalence of underweight and overweight in this age group. The second survey, “Lebanese Food and Nutrition Security Survey” (L-FANUS), was conducted in 2014-2015, and included a representative sample of Lebanese households with 4- to 18-year-old children and adolescents (Jomaa, Naja, Kharroubi, & Hwalla, 2019; Naja et al, 2020). It was planned to assess food security, dietary practices, and the prevalence of overweight and obesity among this age group.

Both surveys were carried out using similar protocols in terms of designs, data collection approach, dietary assessment method, and questionnaires for demographic and socioeconomic characteristics (Nasreddine et al, 2017; Nasreddine et al, 2019; Jomaa et al, 2019; Naja et al, 2020).

C. Study Population:

- Survey 1: It included a representative sample of Lebanese children aged 0 to 4.9 years
- Survey 2: It included a representative sample of Lebanese children and adolescents aged 4 to 18 years

For the purpose of this paper, data related to children aged 6 months to 4.9 years were obtained from survey 1, and data related to children and adolescents aged 5 to 18 years were used from survey 2.

D. Sample Size

For survey 1, sample size calculation was based on a 13% prevalence of overweight and obesity in under-five children (De Onis, Blossner & Borghi, 2010). Therefore, a sample of 1,030 under-five children was needed with a 2% error and a 95% confidence interval. The survey had a final sample size of 1029 participants. Detailed descriptions of the survey's protocol were published elsewhere (Nasreddine et al, 2017; Nasreddine et al, 2019).

For survey 2, the sample size calculation was based on a prevalence of 10.9% of obesity among children aged 6 to 18 years (Nasreddine et al, 2012). Thus, a sample of 1200 children was needed with a 1.8% margin of error and 95% confidence interval. The survey had a final sample size of 1209 participants. Detailed descriptions of the survey's protocol were published elsewhere (Nasreddine et al, 2019; Naja et al, 2020).

E. Sampling Method

The primary sampling unit was the household in both surveys. The households were selected based on a stratified cluster sampling strategy whereby the strata were the six governorates of Lebanon, and the clusters were selected further at the level of districts (Nasreddine et al, 2019). Furthermore, the selection of households, in every district, followed a probability proportional to size approach, where a higher number of participants were gathered from more populous districts. As for the selection of households in districts, it was based on a systematic sampling approach.

To be eligible to participate in survey 1, households had to include a mother and a child between the ages of 0 and 5 years. Children and their mothers were not included if children were of non- Lebanese nationality, were born preterm (<37 weeks), or suffered from any chronic illness, inborn errors of metabolism, or physical malformations that may alter normal dietary intake.

As for the eligibility criteria for survey 2, households had to include a mother and a child between the ages of 4 and 18 years with a Lebanese nationality. Children and their mothers were excluded if the child had any form of medical conditions that may affect growth or nutritional status.

F. Data Collection

In both surveys, data was obtained through face-to-face interviews. For children aged less than 10 years, the interview was conducted with the mother, as a proxy, in the presence of the child. For children aged 10 years or above, the interview was conducted directly with the child, in the presence of the mother for assistance.

Interviews were held in the household setting and lasted for approximately one hour. Trained nutritionists collected data, using age-specific multi-component questionnaires including information on demographic, socioeconomic, and dietary intakes. For the demographic characteristics, the questionnaires included the following: sex of the child, age of the child and age of his/her mother (in years). As for the socioeconomic indicators, the questionnaires consisted of mother's and father's educational levels (primary school or less; intermediate/ high school/ technical diploma; or university degree), maternal employment status (employed/ not employed) and household's monthly income (< 1,000,000 Lebanese pounds; 1,000,001–3,000,000 L.L.; > 3,000,000 L.L.), which are among the generally used indicators of socioeconomic status (Dinsa, Goryakin, Fumagalli, & Suhrcke, 2012). Moreover, survey 2 included an evaluation of the children's physical activity using the modified version of the Children and Youth Physical Activity questionnaire (Corder et al, 2009). Children were categorized as meeting or not meeting the recommendations if they engaged or not in 420 min/week of moderate-to-vigorous activities, respectively, as per the WHO recommendations of physical activity in young individuals (WHO, 2010).

For both surveys, dietary assessment was based on single multiple pass 24-hour recalls, which were done using the USDA multiple pass five step approach (Moshfegh, Borrud, & LaComb, 1999). The steps consisted of the following: 1) quick food list recall, 2) forgotten food list probe 3) time and occasion at which foods were consumed, 4) detailed overall cycle and 5) final probe review of the foods consumed. Moreover, specific attention was made to get information about foods consumed at daycare or school. For young children, and in case another caretaker shared the responsibility of feeding the child, the mother directly consulted with him/her for further information related to the dietary interview.

G. Dietary intake analysis and estimation of free sugar intake

The Nutritionist Pro software (version 5.1.0, 2014, First Data Bank, Nutritionist Pro, Axxya Systems, San Bruno, CA, USA) was used for the analysis of dietary intake data. The USDA database was selected for analysis within the Nutritionist Pro. Dietary data was analyzed for the estimation of the intake of energy (kcal), carbohydrates, protein, total fat, and total sugars in grams per day (g/day); and subsequently the calculation of FS intake (g/day) [93]. As data for lactose were available in the database, lactose intake was subtracted from total sugars. FS intake was calculated based on the 10-step methodology proposed by Kibble white et al. (2017) and which consists of a modification of the method of Louie et al. (2015) that was originally developed for added sugar calculation. As per the definition of the WHO, sugars naturally present in unsweetened fruit juice, syrups, and honey were included in FS estimation (Mesana et al, 2018) while whole fruits and vegetables were assigned a value of zero for FS (Kibblewhite et al, 2017; Yeung & Louis, 2019). For the purpose of our study and based on the approach developed by Wong et al (2019), FS intakes were divided into six categories based on 5% increments in energy intake from FS (%EFS): <5% EFS (C1), 5% to <10% EFS (C2), 10% to <15% EFS (C3), 15% to <20% EFS (C4), 20% to <25% EFS (C5), and ≥25% EFS (C6).

The dietary analysis also determined the intakes of micronutrients including vitamin C, thiamin, riboflavin, niacin, vitamin B6, calcium, phosphorous, magnesium, iron, zinc, sodium, potassium, choline, and pantothenic acid as milligrams per day (mg/day), vitamin B12, vitamin D, vitamin K, biotin, and selenium as micrograms per day (ug/day), folate as micrograms dietary folate equivalents per day (DFE) and vitamin A as micrograms retinol activity equivalent per day (RE). Moreover, Table **20**, shown in Appendix 1, presents the micronutrient reference intakes used for the assessment of dietary intake.

H. Statistical Analysis

Data from both national surveys were analyzed using the Statistical Package for Social Sciences 25.0. Continuous variables were reported as means with standard errors (SE) and medians. On the other hand, categorical variables were presented as frequencies (n) and percentages (%). FS intakes were divided into 6 categories based on 5 percent increments in their contribution to energy intake. Differences in participant characteristics across the FS intake cutoffs were tested for statistical significance using Person's Chi square test for categorical variables and one-way ANOVA for continuous variables, with $p < 0.05$ indicating statistical significance.

The odd ratios (ORs) of not meeting the nutritional reference values (NRVs) were examined at the different FS intake cutoffs using logistic regression analyses. For this purpose, we have first used C1 as the reference category (<5% EFS) in the regression models and assessed the odds of not meeting the respective NRVs at C2, C3, C4, C5 and C6. We have repeated the same analyses using C2 (<10% EFS) as the reference category. Variables that were found to be significantly different across FS categories at the univariate level were adjusted for in the logistic regression analysis models.

In order to assess the associations between adherence to the WHO recommended cutoffs and micronutrient intakes, we have conducted further analyses using logistic regression to examine the odds of not meeting NRVs in those who consume FS at levels ≥5% of energy intake (i.e., C2 to C6) compared to those consuming <5%. The same was done for ≥ 10% EFS (i.e., C3 to C6), in comparison with <10% EFS (C1 and C2). In line with the approach adopted by Wong et al (2019), we have also examined the cutoff of 20% EFS as follows: ≥ 20% EFS (C5 and C6) in comparison with <20% EFS (C1 to C4). A p value of <0.05 was considered statistically significant in all analyses.

I. Ethical Considerations

Both surveys were performed according to the guidelines laid down in the Declaration of Helsinki and were approved by the Institutional Review Board of the American University of Beirut (NUT.LJ.03 and NUT.LN.13). Written informed consent was obtained from mothers prior to enrollment in the study and assent was obtained from children above 6 years of age.

CHAPTER IV

RESULTS

A. Descriptive Data

1. Socio-Demographic & Lifestyle Characteristics

The socio-demographic characteristics of the study participants are shown in Table **3**. Survey 1 consisted of 893 children aged 6 months to 5 years among which 51.4% were males, while survey 2 included 1111 children and adolescents with 53% being females. The majority of mothers in surveys 1 and 2 had intermediate, high school or technical diploma (63.2%- 59.5%), and the same observation was noted for fathers (64.1%-57.3%). Moreover, the majority of participating mothers were unemployed at the time of the survey (83.2% in survey 1 and 76.2% in survey 2). In contrast, more than 90% of fathers were employed, in both surveys.

The distribution of households based on monthly income was similar in both surveys. For instance, 47.4% of the participating households in survey 1 earned between 1,000,000 to 3,000,000 Lebanese pounds (666-2000 US$), compared to 49.3% in survey 2.

Table **3** also shows the physical activity characteristics of the children and adolescents participating in survey 2. More than 50% this age group did not meet the physical activity recommendations of 420 minutes per week of moderate to vigorous activities set by the World Health Organization (WHO).

Table 3: Socio-demographic and lifestyle characteristics of Lebanese children and adolescents, based on 2 nationally representative surveys

	Survey 1			Survey 2		
	6m-5y	**6m-2y**	**2-5y**	**5-18y**	**5-10y**	**10-18y**
	893	370	523	1111	421	690
	n (%)					
Socio-demographic characteristics						
Child's Sex						
Male	459 (51.4)	180 (48.6)	279 (53.3)	532 (47.9)	208 (49.4)	324 (47.0)
Female	434 (48.6)	190 (51.4)	244 (46.7)	579 (52.1)	213 (50.6)	366 (53.0)
Mother's education						
≤ Primary school or less	134 (15)	36 (9.7)	98 (18.7)	244 (21.9)	77 (18.3)	167 (24.2)
Intermediate/ high school/ Technical diploma	573 (64.2)	251 (67.8)	322 (61.6)	660 (59.5)	250 (59.5)	410 (72.5)
≥University degree	186 (20.8)	83 (22.4)	103 (19.7)	207 (18.6)	94 (22.3)	113 (16.4)
Father's education						
≤Primary school or less	186 (21.1)	72 (19.7)	114 (22.2)	312 (28.1)	111 (26.5)	201 (29.6)
Intermediate/ high school/ Technical diploma	564 (64.1)	240 (65.6)	324 (63.0)	637 (57.3)	252 (60.1)	385 (56.8)
≥University degree	130 (14.8)	54 (14.8)	76 (14.8)	148 (13.3)	56 (13.4)	92 (13.6)
Mother's employment status						
Employed	150 (16.8)	70 (18.9)	80 (15.3)	264 (23.9)	308 (73.3)	152 (22.1)
Unemployed	743 (83.2)	300 (81.1)	443 (84.7)	844 (76.2)	308 (73.3)	536 (77.9)
Father's employment status						
Yes	842 (94.3)	354 (95.7)	488 (93.3)	1016 (93.6)	409 (97.6)	607 (91.1)
No	41 (4.6)	15 (4.1)	26 (5.1)	69 (6.4)	10 (2.4)	59 (8.9)
Household monthly income (Lebanese pounds)						
<1,000,000 (<$US 663)	308 (42.5)	140 (48.8)	168 (38.4)	460 (42.2)	174 (41.7)	286 (42.5)
1,000,000-3,000,000 ($US 666–2,000)	343 (47.4)	114 (39.7)	229 (52.4)	538 (49.3)	243 (51.3)	324 (48.1)
>3,000,000 (>$US 2,000)	73 (10.1)	33 (11.5)	40 (9.2)	92 (8.4)	29 (7.0)	63 (9.4)
Governorate						
Beirut	81 (9.1)	25 (6.8)	56 (10.7)	127 (11.4)	54 (12.8)	73 (10.6)
Mount Lebanon	275 (30.8)	110 (29.7)	165 (31.5)	426 (38.3)	176 (41.8)	250 (36.2)
North Lebanon	325 (36.4)	151 (40.8)	174 (33.3)	229 (20.6)	72 (17.1)	157 (22.8)
South and Nabatieh	141 (15.8)	54 (14.6)	87 (16.7)	185 (16.7)	68 (16.2)	117 (17.0)
Beqaa	71 (8.0)	30 (8.1)	41 (7.8)	144 (13.0)	51 (12.1)	93 (13.5)
Lifestyle characteristics						
Physical activity*						
Not meeting recommendations	**N/A**	**N/A**	**N/A**	525 (47.3)	191 (45.4)	334 (48.4)
Meeting recommendations	**N/A**	**N/A**	**N/A**	586 (52.7)	230 (54.6)	356 (51.6)

*Meeting physical activity requirements of 420 minutes per week of moderate to vigorous activities as per the WHO

2. Dietary intake Data

Average dietary intakes of energy, macronutrients, and micronutrients of children aged 6 months to 5 years old are presented in Tables **14a, 14b and 14c** in Appendix 1. The mean energy intake amongst under-five children was estimated at 1346.7 ± 18.5 kcal. In this age group, the mean intake of total sugar was of 74.7 ± 1.2 g/day, with 35.8 ± 1.1 g/day and 27.4 ±1.0 g/day from FS and added sugar respectively. As for their vitamin's intakes, the proportions of children not meeting the DRI ranged from 4% to 91%, the highest being for vitamin D, followed by choline, then calcium, potassium, biotin, folate, vitamin K, vitamin A, pantothenic acid, vitamin C, niacin, vitamin B6, and finally riboflavin. Moreover, the proportions of children not meeting the DRI for minerals ranged from 6% to 16%, the highest being for iron, followed by phosphorous, then zinc, magnesium, and selenium.

Average dietary intakes of energy, macronutrients, and micronutrients amongst children and adolescents aged 5 to 18 years old are presented in Tables **15a, 15b and 15c** in Appendix 1. Mean energy intake was of 1888.8 ± 26.0 kcal in this age group. Mean intake of total sugar was estimated at 77.8 ± 1.5 g/day, with 58.7 ± 1.4 g/day from FS and 52.4 ±1.3 g/day from added sugar. As for their vitamin's intakes, the proportions of children not meeting the DRI ranged from 22% to 99%, the highest being for vitamin D, followed by choline, then calcium, vitamin A, potassium, pantothenic acid, folate, biotin, vitamin B12, vitamin K, vitamin C, riboflavin, vitamin B6, thiamin, and finally niacin. Moreover, the proportions of children not meeting the DRI for minerals ranged from 18% to 99%, the highest being for magnesium, followed by phosphorous, then zinc, iron, and selenium being the lowest.

B. Sample characteristics by free sugar cutoffs

The characteristics of the study participants were examined across the FS intake cutoffs based on 5% increments. These are presented in Table **4** for children aged 6 months to 5 years (survey 1) and in Table **5** for children and adolescents aged 5 to 18 years (survey 2).

Table **4** indicates that there were significant differences in age and energy intake across the FS categories in under-five children, while no other differences were observed for the rest of the sociodemographic characteristics. Significant differences in energy intakes were also noted across FS categories.

Similarly, Table **5** shows that age and energy intakes significantly differed across FS intake categories in children and adolescents aged 5 to 18 years (for age, this was only observed amongst older children aged 10-18 years). In addition, the distribution by governorate differed across FS categories in this age group.

Table 4: Sample characteristics by FS intake categories among 6 months-4.9 years Lebanese children

	Free Sugar intake categories ψ						
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**P-value** *
n (%)	297 (33.2)	227 (25.4)	180 (20.2)	93 (10.4)	56 (6.3)	40 (4.5)	-
Age (mean ± SE, months)	21.1± 0.8	32.5± 1.0	33.3± 1.0	35.1± 1.3	34.8± 1.8	37.7± 1.9	**<0.001**
6months-24months	13.4± 0.4	15.2± 0.6	17.6± 0.7	17.7± 1.1	16.0± 1.8	16.8± 2.8	**<0.001**
24months -60months	39.2± 1.1	40.9± 0.8	39.9± 0.9	39.9± 1.1	39.5± 1.5	40.1± 1.7	0.9
Gender							
% Male	152 (51.2)	113 (49.8)	88 (48.9)	52 (55.9)	25 (44.6)	29 (72.5)	0.09
% Female	145 (48.8)	114 (50.2)	92 (51.1)	41 (44.1)	31 (55.4)	11 (27.5)	
Mother's education n (%)							0.08
Primary school or less	37 (12.5)	24 (10.6)	36 (20.0)	16 (17.2)	10 (17.9)	11 (27.5)	
Intermediate school, high school, or technical diploma	190 (64.0)	153 (67.4)	110 (61.1)	62 (66.7)	34 (60.7)	24 (60.0)	
University degree	70 (23.6)	50 (22.0)	34 (18.9)	15 (6.1)	12 (21.4)	5 (12.5)	
Father's education n (%)							0.6
Primary school or less	55 (19.0)	43 (19.0)	38 (21.5)	25 (27.2)	13 (23.6)	12 (30.0)	
Intermediate school, high school, or technical diploma	193 (66.6)	146 (64.6)	117 (66.1)	51 (55.4)	35 (63.6)	22 (55.0)	
University degree	42 (14.5)	37 (16.4)	22 (12.4)	16 (17.4)	7 (12.7)	6 (15.0)	
Mother's employment status n (%)							0.6
Employed	57 (19.2)	38 (16.7)	23 (12.8)	17 (18.3)	8 (14.3)	7 (17.5)	
Unemployed	240 (80.8)	189 (83.3)	157 (87.2)	76 (81.7)	48 (85.7)	33 (82.5)	
Father's employment status n (%)							0.2
Employed (%)	275 (92.6)	215 (94.7)	172 (95.6)	91 (97.8)	49 (95.5)	40 (100.0)	
Unemployed (%)	22 (7.4)	12 (5.3)	8 (4.4)	2 (2.2)	7 (4.5)	0 (2.0)	
Household monthly income n (%)							0.2
<1,000,000 (<$US 663)	103 (34.7)	74 (32.6)	72 (40.0)	31 (33.4)	16 (28.6)	12 (30.0)	
1,000,001-3,000,000 ($US 666–2,000)	101 (34.0)	96 (42.3)	69 (38.4)	30 (32.3)	25 (44.7)	22 (55.0)	
>3,000,000 (>$US 2,000)	30 (10.1)	20 (8.8)	11 (6.1)	8 (8.6)	3 (5.4)	1 (2.5)	
Refused to answer/ Doesn't know	63 (21.2)	37 (16.3)	28 (15.5)	24 (25.7)	12 (21.3)	5 (12.5)	
Governate n (%)							0.1
Beirut	22 (7.4)	23 (10.1)	17 (9.4)	8 (8.6)	8 (14.3)	3 (7.5)	
Beqaa	22 (7.4)	20 (8.8)	16 (8.9)	2 (2.2)	7 (12.5)	4 (10.0)	
Mount Lebanon	94 (31.6)	64 (28.2)	56 (31.1)	24 (25.8)	22 (39.3)	15 (37.5)	
North Lebanon	115 (38.7)	85 (37.4)	66 (36.7)	39 (41.9)	13 (23.2)	7 (17.5)	
South Lebanon	44 (14.8)	35 (15.4)	25 (13.9)	20 (21.5)	6 (10.7)	11 (27.5)	
Total energy intake (mean ± SE, Kcal)	1072.4± 27.0	1485.7± 36.6	1469.8± 40.8	1549.2± 57.3	1410.3± 72.9	1480.7± 75.5	**<0.001**

* Chi square and ANOVA were used to calculate p-value

ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

Table 5: Sample characteristics by FS intake categories among 5-18 years Lebanese participants

	Free Sugar intake categories ψ						
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**P-value** *
n (%)	178 (16.0)	278 (25.0)	282 (25.4)	207 (18.6)	108 (9.7)	58 (5.2)	-
Age (mean ± SE, months)	144.0 ±3.4	134.2 ±2.4	136.3 ±2.7	140.8 ±3.0	137.1 ±4.1	136.8 ±6.2	0.2
5-10y	91.6± 2.4	94.7± 1.6	90.6± 1.6	93.1± 2.1	89.2± 2.7	92.4± 3.8	0.6
10-18y	170.6± 2.5	160.8± 2.1	168.6± 2.2	165.2± 2.6	162.1±3.3	172.9± 5.0	**0.01**
Gender							0.1
% Male	78 (43.8)	138 (49.6)	131 (46.5)	114 (55.1)	50 (46.3)	21 (36.2)	
% Female	100 (56.2)	140 (50.4)	151 (53.5)	93 (44.9)	58 (53.7)	37 (63.8)	
Mother's education n (%)							0.5
No school	6 (3.4)	10 (3.6)	9 (3.2)	2 (1.0)	0 (0.0)	1 (1.7)	
Primary school	28 (15.7)	51 (18.3)	56 (19.9)	43 (20.8)	24 (22.2)	14 (24.1)	
Intermediate school	52 (29.2)	86 (30.9)	80 (28.4)	65 (31.4)	29 (26.9)	18 (31.0)	
High school	37 (20.8)	45 (16.2)	52 (18.4)	50 (24.2)	17 (15.7)	14 (24.1)	
Technical diploma	19 (10.7)	28 (10.1)	30 (10.6)	20 (9.7)	13 (12.0)	5 (8.6)	
University degree	36 (20.2)	58 (20.9)	55 (19.5)	27 (13.0)	25 (23.1)	6 (10.3)	
Father's education n (%)							0.1
No school	8 (4.6)	21 (7.6)	8 (2.9)	8 (3.9)	2 (1.9)	3 (5.3)	
Primary school	29 (16.6)	71 (25.6)	66 (23.7)	59 (28.9)	22 (20.8)	15 (26.3)	
Intermediate school	61 (34.9)	78 (28.2)	97 (34.9)	51 (25.0)	32 (30.2)	18 (31.6)	
High school	30 (17.1)	50 (18.1)	56 (20.1)	38 (18.6)	19 (17.9)	10 (17.5)	
Technical diploma	19 (10.9)	19 (6.9)	18 (6.5)	24 (11.8)	14 (13.2)	3 (5.3)	
University degree	28 (16.0)	38 (13.7)	33 (11.9)	24 (11.8)	17 (16.0)	8 (14.0)	
Mother's employment status n (%)							0.7
Employed	38 (21.4)	78 (28.1)	69 (24.2)	40 (18.9)	30 (27.1)	12 (20.7)	
Unemployed	140 (78.6)	200 (71.9)	213 (75.8)	167 (81.1)	78 (72.9)	46 (79.3)	
Father's employment status n (%)							0.3
Employed	167 (93.6)	260 (93.4)	261 (92.3)	193 (93.1)	104 (96.3)	57 (98.2)	
Unemployed	11 (6.4)	18 (6.6)	21 (7.7)	14 (6.9)	4 (3.7)	1 (1.8)	
Household monthly income n (%)							0.07
<1,000,000 (<$US 663)	64 (36.5)	118 (43.2)	131 (47.1)	86 (42.2)	38 (36.9)	23 (40.3)	
1,000,001-3,000,000 ($US 666–2,000)	89 (50.8)	131 (48.0)	127 (45.6)	108 (53.0)	58 (56.3)	25 (43.9)	
>3,000,000 (>$US 2,000)	22 (12.6)	24 (8.8)	20 (7.2)	10 (4.9)	7 (6.8)	9 (15.8)	
Governorate n (%)							**0.04**
Beirut	20 (11.2)	31 (11.2)	39 (13.8)	18 (8.7)	12 (11.1)	7 (12.1)	
Beqaa	20 (11.2)	42 (15.1)	36 (12.8)	23 (11.1)	18 (16.7)	5 (8.6)	
Mount Lebanon	77 (43.3)	105 (37.8)	100 (35.5)	85 (41.1)	37 (34.3)	22 (37.9)	
North Lebanon	27 (15.2)	65 (23.4)	65 (23.0)	50 (24.2)	14 (13.0)	8 (13.8)	
South Lebanon	20 (19.1)	31 (12.6)	39 (14.9)	31 (15.0)	27 (25.0)	16 (27.6)	
Total energy intake (mean ± SE, Kcal)	1669.5 ± 61.2	1982.2 ± 50.5	1950.1 ±52.5	2009.0 ±61.0	1827.5 ±77.3	1500.6 ±116.2	**<0.001**

* Chi square and ANOVA were used to calculate p-value
ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

C. Micronutrient intake across the free sugar intake categories

Mean micronutrient intakes across the FS intake categories are presented in Table **6** for children aged 6 months to 5 years and Table **7** for children and adolescents aged 5 to 18 years and are expressed as absolute daily intake as well as intake per 1000 kcal.

As shown in Table **6**, significant differences in the absolute intake of the majority of micronutrient were observed across the FS intake categories, except for vitamin B12, vitamin K and iron. The highest intake levels for most nutrients (15 out of 20 nutrients) were observed at the C2 category, where participants had a FS intake level between 5 and 10% EI. On the other hand, participants with more than 25% energy intake from FS (C6) and those that had <5% energy intake from FS (C1) have the lowest intakes of most nutrients (9/20 nutrients (C6); 9/20 nutrients (C1)).

Table **6** also showed that there were significant differences in micronutrient density (intake per 1000 kcal), across the various FS intake categories and this was observed for most nutrients, except for vitamin C, vitamin B6, vitamin B12, potassium and biotin. The highest micronutrient densities were observed in the first FS cutoff (<5% energy intake from FS), followed by the second FS cutoff (5% to 10% EFS) except for vitamin C, biotin, and potassium. On the other hand, children with >25% EFS had the lowest micronutrient densities for most nutrients (15/20 nutrients)

Similar results were observed for children and adolescents aged 5 to 18 years. In fact, Table **7** shows that, there was a significant difference in the absolute intake of the majority of micronutrient across the FS intake categories, except for vitamin C, niacin, vitamin B12 and vitamin A. For 11 micronutrients, the highest intake levels were observed at the second FS cutoff (5%-10% EFS), while the highest intakes for other 5 other nutrients were observed in the first free-sugar cutoff (<5% EFS). Moreover, participants with >25% EFS (C6) had the lowest intake of most nutrients (15/20 nutrients in absolute intake), while those with 20-25% EFS (C5) had the lowest intakes for 4 nutrients including folate, vitamin A, vitamin K, and iron.

The results of Table **7** also showed there was significant differences in micronutrient density (intake per 1000 kcal), across the various FS intake categories, and this was observed for most nutrients, except for vitamin C, niacin, and vitamin B12. In fact, the highest micronutrient densities were found in the first FS cutoff (<5% EFS), followed by the second free sugar cutoff (5% to 10% EFS), except for vitamin C. Moreover, participants in this age group with 20%- 25% EFS (C5) and >25% EFS (C6) had the lowest micronutrient densities for most nutrients (10/20 nutrients (C5); 10/20 nutrients (C6)).

Table 6: Absolute micronutrient daily intakes and dietary micronutrient densities (per 1000 kcal) across the six FS intake categories in Lebanese under-five children (6 months-4.9 years)

	Free Sugar intake categories ψ							
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**P-value***	**P trend[a]**
n (%)	297 (33.2)	227 (25.4)	180 (20.2)	93 (10.4)	56 (6.3)	40 (4.5)	-	-
Vitamin C (mg/day)								
Absolute intake	57.4± 1.9	73.6± 4.0	76.2± 4.6	85.5± 8.4	91.8± 11.5	84.8± 12.6	**<0.001**	**<0.001**
Intake per 1000 Kcal	58.3± 1.7	50.7± 2.4	53.5± 3.1	55.7± 3.1	64.3± 8.6	59.7± 8.7	0.2	0.1
Thiamin (mg)								
Absolute intake	0.92± 0.03	1.1± 0.03	1.0± 0.03	1.1± 0.05	0.9± 0.05	0.81± 0.05	**<0.001**	**<0.001**
Intake per 1000 Kcal	0.80± 0.15	0.76± 0.14	0.73± 0.016	0.71± 0.02	0.69± 0.25	0.55± 0.03	**<0.001**	**<0.001**
Riboflavin (mg)								
Absolute intake	1.1± 0.03	1.3± 0.03	1.3±0.05	1.2± 0.05	1.0± 0.9	1.0±0.7	**<0.001**	**<0.001**
Intake per 1000 Kcal	1.0± 0.02	0.93±0.02	0.88±0.03	0.84±0.04	0.77±0.05	0.71±0.04	**<0.001**	**<0.001**
Niacin (mg/day)								
Absolute intake	9.8± 0.4	12.9± 0.5	12.7± 0.6	11.8± 0.6	10.1±0.7	10.0±0.9	**<0.001**	**<0.001**
Intake per 1000 Kcal	9.0±0.2	8.7± 0.22	8.6± 0.3	7.7± 0.3	7.4± 0.4	6.9± 0.6	**<0.001**	**<0.001**
Vitamin B6 (mg/day)								
Absolute intake	0.71±0.02	1.0±0.03	1.0±0.04	1.0±0.05	0.92±0.06	0.91±0.07	**<0.001**	**<0.001**
Intake per 1000 Kcal	0.69± 0.02	0.69± 0.02	0.70± 0.23	0.65± 0.03	0.67± 0.04	0.66±0.04	0.7	0.5
Folate (ug dietary folate equivalent/day)								
Absolute intake	184.1± 6.7	239.8± 12.7	205.7± 11.1	219.2± 15.4	215.3± 19.2	154.7± 17.6	**<0.001**	**<0.001**
Intake per 1000 Kcal	177.6± 5.3	161.1±6.0	145.1±6.7	143.2± 9.4	152.0± 11.8	111.6± 12.7	**<0.001**	**<0.001**
Vitamin B12 (ug/day)								
Absolute intake	2.2± 0.2	2.6± 0.1	2.9± 0.3	2.5± 0.2	2.9± 1.0	1.8± 0.2	0.4	0.1
Intake per 1000 Kcal	2.0± 0.1	1.9± 0.09	1.9± 0.2	1.8± 0.2	1.9± 0.5	1.2± 0.1	0.5	0.3
Calcium (mg/day)								
Absolute intake	594.7±21.4	701.7± 21.4	645.7± 27.7	638.0± 34.2	515.7± 37.0	583.9± 50.7	**0.001**	**<0.001**
Intake per 1000 Kcal	572.6± 13.9	503.5± 15.5	459.3± 17.5	442.5± 24.3	389.9± 34.4	403.5± 35.1	**<0.001**	**<0.001**
Phosphorous (mg/day)								
Absolute intake	573.7± 21.6	855.4± 26.8	839.1± 32.3	781.5± 28.3	706.4± 44.0	723.5± 13.3	**<0.001**	**<0.001**

Intake per 1000 Kcal	518.3± 12.0	583.2± 12.9	574.2±15.6	531.9± 18.4	524.7± 25.1	489.3± 31.1	**0.001**	**<0.001**
Magnesium (mg/day)								
Absolute intake	110.5± 3.9	171.5± 5.4	175.4± 6.6	173.6± 8.0	159.3± 10.1	160.7± 13.2	**<0.001**	**<0.001**
Intake per 1000 Kcal	99.4± 2.1	114.6± 2.2	118.2±2.4	112.3± 2.9	114.6± 4.6	108.9± 6.7	**<0.001**	**<0.001**
Vitamin D (ug/day)								
Absolute intake	238.4± 10.2	189.7± 9.8	145.6± 11.3	131.31±13.6	104.9± 14.0	129.8± 21.3	**<0.001**	**<0.001**
Intake per 1000 Kcal	240.5± 9.9	146.9± 8.4	110.1± 7.9	98.7± 11.2	80.7± 11.8	90.5± 15.3	**<0.001**	**<0.001**
Vitamin A (ug retinol activity equivalent/day)								
Absolute intake	482.3± 27.5	403.5± 16.5	397.9± 46.1	351.5± 35.3	374.0± 96.0	297.2± 46.1	**0.05**	**0.02**
Intake per 1000 Kcal	523.2± 19.7	391.6± 18.9	372.8± 31.1	333.4± 41.8	333.2±59.9	324.7± 45.8	**<0.001**	**<0.001**
Vitamin K (ug/day)								
Absolute intake	67.7± 5.3	73.6±5.2	63.1±5.6	69.7± 8.2	68.6± 10.9	41.6± 11.4	0.3	0.1
Intake per 1000 Kcal	62.0± 4.4	50.7± 3.3	44.1± 3.8	43.2± 4.4	46.4± 6.8	27.6± 5.6	**0.001**	**<0.001**
Iron (mg/day)								
Absolute intake	8.4± 0.3	9.6± 0.6	8.7± 0.5	8.7± 0.6	7.7± 0.5	7.4± 0.6	0.2	0.1
Intake per 1000 Kcal	8.1± 0.3	6.6± 0.3	5.9± 0.3	5.4± 0.3	5.6± 0.4	5.1± 0.4	**<0.001**	**<0.001**
Zinc (mg/day)								
Absolute intake	5.6± 0.2	6.7± 0.2	6.4±0.2	6.3± 0.3	5.5± 0.4	4.7± 0.3	**<0.001**	**<0.001**
Intake per 1000 Kcal	5.2± 1.7	4.6± 0.1	4.4±0.1	4.2± 0.2	4.1± 0.2	3.2± 0.2	**<0.001**	**<0.001**
Potassium (mg/day)								
Absolute intake	1384.2± 41.9	2020.6± 60.6	2003.6± 66.2	1935.3± 87.0	1900.9± 129.8	1868.8± 132.4	**<0.001**	**<0.001**
Intake per 1000 Kcal	1289.7± 23.7	1368.2± 26.5	1385.5± 30.3	1280.1± 43.4	1364.2± 65.1	1290.8± 71.3	0.08	0.06
Biotin (ug/day)								
Absolute intake	10.3± 0.6	16.0± 1.0	14.5± 1.0	14.5± 1.0	14.4± 1.7	17.0± 4.7	**<0.001**	**<0.001**
Intake per 1000 Kcal	10.2± 0.5	11.0± 0.5	10.1± 0.5	10.5± 1.4	10.1± 1.0	12.9± 3.9	0.7	0.5
Choline (mg/day)								
Absolute intake	142.8± 4.9	202.6± 7.6	193.0± 8.5	179.9± 8.5	170.8± 144.3	173.8± 3.4	**<0.001**	**<0.001**
Intake per 1000 Kcal	138.8± 3.9	140.9± 4.4	133.1± 4.5	121.7± 5.5	124.2± 8.9	97.8± 4.8	**<0.001**	**<0.001**
Pantothenic Acid								
(mg/day)	3.2± 0.07	3.7± 0.1	3.3± 0.1	3.0± 0.1	2.9± 0.2	2.8± 0.2	**<0.001**	**<0.001**
Absolute intake	3.1± 0.05	2.6± 0.05	2.3± 0.07	2.1± 0.1	2.1± 0.1	1.9± 0.1	**<0.001**	**<0.001**
Intake per 1000 Kcal								
Selenium (ug/day)								

Absolute intake	39.1± 1.6	59.3± 3.1	54.7±2.7	54.9± 2.8	44.6± 3.1	42.3± 3.2	**<0.001**	**<0.001**
Intake per 1000 Kcal	34.7± 1.0	39.3± 1.4	36.7± 1.3	35.9± 1.4	32.7±2.0	28.9± 1.6	**0.003**	**<0.001**
Total energy intake (mean ± SE, Kcal)	1072.4± 27.0	1485.7± 36.6	1469.8± 40.8	1549.2± 57.3	1410.3± 72.9	1480.7± 75.5	**<0.001**	-

*ANOVA was used to calculate p-value

ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

[a]*p* for trend was assessed by logistic regression with adjustment for the same covariates as in the main analysis

Table 7: Absolute micronutrient daily intakes and dietary micronutrient densities (per 1000 kcal) across the six FS intake categories among 5-18 years Lebanese participants

	Free Sugar intake cutoffs ψ							
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**P-value***	**P trend[a]**
n (%)	178 (16.0)	278 (25.0)	282 (25.4)	207 (18.6)	108 (9.7)	58 (5.2)	-	-
Vitamin C (mg/day)								
Absolute intake	62.5 ±4.01	74.3 ±4.3	75.7 ±4.6	74.8 ±5.2	67.8 ±8.6	83.5 ±13.3	0.3	0.2
Intake per 1000 Kcal	39.0±2.5	39.4± 2.2	40.8±2.5	40.3± 2.8	38.3± 4.8	63.8± 8.9	**0.003**	**<0.001**
Thiamin (mg)								
Absolute intake	1.1 ±0.04	1.3 ±0.04	1.2 ±0.04	1.2 ±0.04	1.1 ±0.05	0.81 ±0.07	**<0.001**	**<0.001**
Intake per 1000 Kcal	0.71± 0.02	0.69± 0.01	0.65± 0.02	0.60± 0.01	0.60± 0.02	0.56± 0.04	**<0.001**	**<0.001**
Riboflavin (mg)								
Absolute intake	1.2 ±0.06	1.2 ±0.5	1.2 ±0.05	1.1 ±0.06	1.0 ±0.5	0.82 ±0.6	**0.001**	**<0.001**
Intake per 1000 Kcal	0.73± 0.03	0.65± 0.02	0.65± 0.03	0.60± 0.03	0.55± 0.2	0.54± 0.03	**0.003**	**<0.001**
Niacin (mg/day)								
Absolute intake	16.6 ±0.9	18.0 ±0.7	20.6 ±3.4	20.0 ±4.6	13.8 ±0.8	10.1 ±0.9	0.4	0.1
Intake per 1000 Kcal	10.5± 6.2	9.1± 0.2	11.1± 2.1	11.5± 54.9	7.7±0.4	6.9± 0.4	0.8	0.3
Vitamin B6 (mg/day)								
Absolute intake	1.3 ±0.07	1.4 ±0.05	1.3 ±0.05	1.2 ±0.06	1.1 ±0.07	0.83 ±0.07	**<0.001**	**<0.001**
Intake per 1000 Kcal	0.81± 0.03	0.70± 0.02	0.69±0.01	0.59± 0.02	0.59± 0.03	0.58± 0.04	**<0.001**	**<0.001**

Folate (ug dietary folate equivalent/day)								
Absolute intake	265.2 ±15.9	262.5 ±11.3	267.8 ±12.2	231.4 ±12.5	190.5 ±12.2	205.1 ±19.8	**0.001**	**<0.001**
Intake per 1000 Kcal	165.4± 8.7	136.4± 4.9	139.9± 5.3	118.3± 5.2	107.8± 6.0	148.2± 12.2	**<0.001**	**<0.001**
Vitamin B12 (ug/day)								
Absolute intake	3.2 ±0.8	2.8 ±0.6	2.7 ±0.4	2.4 ±0.3	1.6 ±0.1	1.2 ±0.2	0.3	0.1
Intake per 1000 Kcal	2.3± 0.5	1.3±0.2	1.6± 0.3	1.2± 0.1	0.97± 0.1	0.90± 0.1	0.09	0.06
Calcium (mg/day)								
Absolute intake	647.9 ±34.6	646.9 ±22.5	669.8 ±25.2	679.0 ±28.3	560.6 ±30.8	405.1 ±41.0	**<0.001**	**<0.001**
Intake per 1000 Kcal	411.2± 19.1	346.1± 11.0	363.2± 12.0	349.2± 12.6	320.4± 13.9	286.5± 21.9	**<0.001**	**<0.001**
Phosphorous (mg/day)								
Absolute intake	841.5 ±32.2	889.9 ±26.1	863.2 ±25.0	826.6 ±29.8	725.6 ±36.2	595.2 ±47.1	**<0.001**	**<0.001**
Intake per 1000 Kcal	523.2± 12.9	461.0± 7.9	458.0± 8.6	414.1± 8.2	402.3± 11.9	406.4± 16.2	**<0.001**	**<0.001**
Magnesium (mg/day)								
Absolute intake	221.1 ±8.9	243.5 ±10.0	229.6 ±6.4	227.7 ±7.7	208.3 ±12.5	164.9 ±10.8	**0.001**	**<0.001**
Intake per 1000 Kcal	139.1± 3.7	124.4± 2.6	121.2± 2.1	116.4± 2.5	113.9± 3.3	118.4± 4.0	**<0.001**	**<0.001**
Vitamin D (ug/day)								
Absolute intake	1.8 ±0.5	1.3±0.1	1.2 ±0.09	1.3 ±0.2	0.71 ±0.1	0.62±0.2	**0.03**	**0.002**
Intake per 1000 Kcal	1.2± 0.3	0.71± 0.07	0.71± 0.07	0.65± 0.07	0.47± 0.08	0.38± 0.09	**0.007**	**<0.001**
Vitamin A (ug retinol activity equivalent/day)								
Absolute intake	202.0 ±105.9	75.7 ±7.1	138.1 ±39.7	97.7 ±39.7	45.5 ±10.4	81.1 ±35.6	0.3	0.2
Intake per 1000 Kcal	298.5± 45.8	187.2± 21.1	212.4± 28.7	192.6± 19.3	162.4± 23.4	184.9± 27.2	0.05	**0.03**
Vitamin K (ug/day)								
Absolute intake	190.5 ±17.5	191.0 ±16.7	170.6 ±15.2	150.0 ±16.7	100.7 ±18.1	165.0 ±7.2	**0.004**	**<0.001**
Intake per 1000 Kcal	118.4± 10.1	94.5± 7.4	85.7± 7.6	73.6± 6.8	60.7± 7.7	94.7± 25.7	**0.001**	**<0.001**
Iron (mg/day)								
Absolute intake	10.7 ±0.6	11.4 ±0.4	11.8 ±0.5	10.7 ±0.4	8.9 ±0.4	9.6 ±0.9	**0.008**	**<0.001**
Intake per 1000 Kcal	6.4± 0.3	5.9± 0.2	5.9± 0.2	5.4± 0.2	4.9± 0.2	6.3± 0.4	**<0.001**	**<0.001**
Zinc (mg/day)								
Absolute intake	8.0 ±0.4	8.8 ±0.4	8.2 ±0.3	7.4 ±0.3	6.4 ±0.3	5.2 ±0.4	**<0.001**	**<0.001**
Intake per 1000 Kcal	5.0± 0.2	4.4± 0.1	4.3± 0.1	3.8±0.1	3.6± 0.2	3.5± 0.2	**<0.001**	**<0.001**
Potassium (mg/day)								
Absolute intake	2178.0 ±95.5	2343.8 ±75.2	2293.0 ±71.0	2204.8 ±79.2	2008.7 ±115.9	1590.5 ±110.7	**<0.001**	**<0.001**
Intake per 1000 Kcal	1343.9± 41.6	1206.8± 24.8	1193.8± 22.4	1112.5± 24.5	1093.0± 37.0	11492± 57.5	**<0.001**	**<0.001**

Biotin (ug/day)								
Absolute intake	20.5 ±1.5	20.7 ±1.1	19.2 ±1.1	18.6 ±1.1	16.7 ±1.6	9.1 ±1.2	**<0.001**	**<0.001**
Intake per 1000 Kcal	12.2± 0.8	10.4± 0.4	10.2± 0.6	9.8± 0.6	8.8± 0.7	6.6± 0.7	**0.001**	**<0.001**
Choline (mg/day)								
Absolute intake	228.9 ±12.0	218.1 ±10.0	208.1 ±7.5	191.6 ±9.2	160.5 ±9.5	130.6 ±12.3	**<0.001**	**<0.001**
Intake per 1000 Kcal	145.8± 6.8	111.3± 4.0	116.0± 4.6	99.8± 4.7	91.3± 5.5	93.6± 7.1	**<0.001**	**<0.001**
Pantothenic Acid								
(mg/day)	3.6 ±0.2	3.7 ±0.1	3.5 ±0.1	3.3 ±0.1	2.7 ±0.1	2.2 ±0.2	**<0.001**	**<0.001**
Absolute intake	2.2± 0.07	1.9± 0.04	1.8± 0.05	1.7± 0.05	1.5± 0.05	1.6± 0.1	**<0.001**	**<0.001**
Intake per 1000 Kcal								
Selenium (ug/day)								
Absolute intake	71.4 ±3.4	80.2 ±3.2	74.1 ±2.5	66.6 ±2.7	57.8 ±3.1	41.6 ±3.7	**<0.001**	**<0.001**
Intake per 1000 Kcal	45.5± 1.8	40.9± 1.2	39.9± 1.1	33.9± 1.0	33.0± 1.6	27.7± 2.0	**<0.001**	**<0.001**
Total energy intake (mean ± SE, Kcal)	1669.5 ± 61.2	1982.2 ± 50.5	1950.1 ±52.5	2009.0 ±61.0	1827.5 ±77.3	1500.6 ±116.2	**<0.001**	**-**

*ANOVA was used to calculate p-value

ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

[a]*p* for trend was assessed by logistic regression with adjustment for the same covariates as in the main analysis

D. Proportions of children and adolescents not meeting the nutritional reference values across the various free sugar intake categories

Table **8** and Table **9** present the proportions of participants not meeting the nutritional reference values (NRVs) across the various FS intake categories in children aged 6 months to 5 years and those aged 5 to 18 years, respectively.

For under-five children, there were significant differences in these proportions for all micronutrients, except for biotin. The proportions of children not meeting the NRVs were the highest in the C6 category (>25% EFS) for 9 nutrients including thiamin, riboflavin, niacin, folate, vitamin B12, vitamin K, iron, zinc, and selenium. Moreover, children in the C5 category (20-25% EFS) had the highest proportions of children not meeting the NRVs for 4 nutrients: calcium, vitamin D, vitamin A, and pantothenic acid. In addition, high percentages of not meeting the NRVs for a number of nutrients were observed in the C1 category (<5% EFS), including vitamin C, vitamin B6, phosphorous, magnesium, potassium, biotin, and choline. On the other hand, the C2 category (5-10% EFS) had the lowest proportions of children not meeting the NRVs for most of the nutrients (14/20 nutrients) including riboflavin, niacin, vitamin B6, folate, vitamin B12, calcium, phosphorous, vitamin A, zinc, potassium, biotin, choline, pantothenic acid, and selenium.

As for children and adolescents aged 5-18 years, there were significant differences in these proportions for all micronutrients except for vitamin C, calcium, vitamin D, vitamin K, and iron. In fact, the proportions of children and adolescents not meeting the NRVs were the highest in the C6 category (>25% EFS) for all nutrients except vitamin C, folate, and vitamin A. Moreover, children in the C5 category (20-25%EFS) had the highest proportions of participants not meeting the NRVs of the following 3 nutrients: vitamin C, folate, and vitamin

A. On the other hand, Table **9** showed that the C2 category (5-10% EFS) had the lowest proportions of children and adolescents not meeting the NRVs for most of nutrients (14/20 nutrients) including vitamin C, thiamin, riboflavin, niacin, vitamin B6, folate, magnesium, vitamin D, iron, zinc, potassium, biotin, pantothenic acid, and selenium.

Table 8: Proportions of under-five children (6months-4.9 years) not meeting the NRVs across the various free sugar intake categories

	Free Sugar intake categories Ψ							
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**P-value***	**P trend[a]**
n (%)	297 (33.2)	227 (25.4)	180 (20.2)	93 (10.4)	56 (6.3)	40 (4.5)	-	-
Vitamin C	69 (23.2)	26 (11.5)	22 (12.2)	14 (15.1)	6 (10.7)	6 (15.0)	**0.003**	**0.001**
Thiamin	36 (12.1)	6 (9.0)	11 (6.1)	4 (4.3)	4 (7.1)	6 (15.0)	**0.001**	**<0.001**
Riboflavin	24 (8.1)	3 (1.3)	5 (2.8)	3 (3.2)	7 (12.5)	5 (12.5)	**<0.001**	**<0.001**
Niacin	50 (16.8)	16 (7.0)	17 (9.4)	11 (11.8)	6 (10.7)	12 (30.0)	**<0.001**	**<0.001**
Vitamin B6	48 (16.2)	11 (4.8)	22 (12.2)	9 (9.7)	3 (5.4)	6 (15.0)	**0.001**	**<0.001**
Folate	87 (29.3)	53 (23.3)	55 (30.6)	29 (31.2)	16 (28.6)	22 (55.0)	**0.005**	**0.002**
Vitamin B12	40 (13.5)	24 (10.6)	26 (14.4)	11 (11.8)	10 (17.9)	10 (25.0)	**0.001**	**<0.001**
Calcium	107 (36.0)	73 (32.2)	83 (46.1)	45 (48.4)	30 (53.6)	21 (52.5)	**<0.001**	**<0.001**
Phosphorous	77 (25.9)	10 (4.4)	21 (11.7)	6 (6.5)	6 (10.7)	6 (15.0)	**<0.001**	**<0.001**
Magnesium	97 (32.7)	24 (10.6)	16 (8.9)	10 (10.8)	4 (7.1)	4 (10.0)	**<0.001**	**<0.001**
Vitamin D	233 (78.5)	205 (90.3)	170 (94.4)	89 (95.7)	55 (98.2)	39 (97.5)	**<0.001**	**<0.001**
Vitamin A	104 (35.0)	42 (18.5)	43 (23.9)	31 (33.3)	25 (44.6)	14 (35.0)	**<0.001**	**<0.001**
Vitamin K	60 (20.2)	60 (26.4)	68 (37.8)	42 (45.2)	23 (41.1)	25 (62.5)	**<0.001**	**<0.001**
Iron	69 (23.2)	29 (12.8)	21 (11.7)	13 (14.0)	7 (12.5)	10 (25.0)	**0.006**	**0.004**
Zinc	40 (13.5)	10 (4.4)	17 (9.4)	8 (8.6)	5 (8.9)	6 (15.0)	**0.02**	**0.01**
Potassium	197 (66.3)	112 (49.3)	94 (52.2)	50 (53.8)	34 (60.7)	25 (62.5)	**0.002**	**<0.001**
Biotin	119 (43.0)	66 (29.5)	62 (35.0)	37 (40.2)	21 (38.9)	15 (40.5)	0.07	0.06
Choline	246 (82.8)	142 (62.6)	116 (64.4)	65 (69.9)	42 (75.0)	33 (82.5)	**<0.001**	**<0.001**
Pantothenic Acid	52 (17.5)	26 (11.5)	36 (20.0)	21 (22.6)	22 (39.3)	12 (30.0)	**<0.001**	**<0.001**
Selenium	78 (26.3)	12 (5.3)	16 (8.9)	4 (4.3)	7 (12.5)	11 (27.5)	**<0.001**	**<0.001**

* Chi square was used to calculate p-value

ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

[a]*p* for trend was assessed by logistic regression with adjustment for the same covariates as in the main analysis

Table 9: Proportions of children and adolescents (5-18 years) not meeting the NRVs across the various free sugar intake categories

	Free Sugar intake categories Ψ							
	C1	C2	C3	C4	C5	C6	P-value*	P trend[a]
n (%)	178	278	282	207	108	58	-	-
Vitamin C	82 (46.1)	94 (33.8)	109 (38.7)	80 (38.6)	50 (46.3)	23 (39.7)	0.1	0.07
Thiamin	48 (27.0)	50 (18.0)	56 (19.9)	50 (24.2)	29 (26.9)	30 (51.7)	**<0.001**	**<0.001**
Riboflavin	61 (34.3)	71 (25.5)	81 (28.7)	72 (34.8)	43 (39.8)	35 (60.3)	**<0.001**	**<0.001**
Niacin	44 (24.7)	41 (14.7)	47 (16.7)	53 (25.6)	32 (29.6)	27 (46.6)	**<0.001**	**<0.001**
Vitamin B6	53 (29.8)	60 (21.6)	65 (23.0)	66 (31.9)	34 (31.5)	32 (55.2)	**<0.001**	**<0.001**
Folate	102 (57.3)	153 (55.0)	164 (58.2)	138 (66.7)	75 (69.4)	38 (65.5)	**0.03**	**0.01**
Vitamin B12	85 (47.8)	133 (47.8)	133 (47.2)	106 (51.2)	68 (63.0)	41 (70.7)	**0.002**	**<0.001**
Calcium	147 (82.6)	234 (84.2)	232 (82.3)	174 (84.1)	94 (87.0)	53 (91.4)	0.5	0.3
Phosphorous	107 (60.1)	146 (52.5)	145 (51.4)	121 (58.5)	72 (66.7)	42 (72.4)	**0.006**	**0.004**
Magnesium	90 (50.6)	105 (37.8)	125 (44.3)	99 (47.8)	59 (54.6)	39 (67.2)	**<0.001**	**<0.001**
Vitamin D	176 (98.9)	275 (98.9)	282 (100.0)	206 (99.5)	108 (100.0)	58 (100.0)	0.4	0.1
Vitamin A	113 (63.5)	202 (72.7)	204 (72.3)	164 (79.2)	89 (82.4)	47 (81.0)	**0.002**	**<0.002**
Vitamin K	66 (37.1)	106 (38.1)	109 (38.7)	85 (41.1)	55 (50.9)	31 (53.4)	0.06	0.08
Iron	47 (26.4)	50 (18.0)	59 (20.9)	42 (20.3)	23 (21.3)	17 (29.3)	0.2	0.09
Zinc	76 (42.7)	108 (38.8)	107 (37.9)	98 (47.3)	54 (50.0)	40 (69.0)	**<0.001**	**<0.001**
Potassium	136 (76.4)	184 (66.2)	192 (68.1)	152 (73.4)	83 (76.9)	49 (84.5)	**0.01**	**0.007**
Biotin	103 (59.9)	136 (50.9)	158 (58.7)	123 (60.9)	62 (61.4)	49 (86.0)	**<0.001**	**<0.001**
Choline	147 (82.6)	233 (83.8)	238 (84.4)	192 (92.8)	102 (94.4)	56 (96.6)	**<0.001**	**<0.001**
Pantothenic Acid	114 (64.0)	166 (59.7)	180 (63.8)	157 (75.8)	86 (79.6)	51 (87.9)	**<0.001**	**<0.001**
Selenium	38 (21.3)	35 (12.6)	38 (13.5)	43 (20.8)	25 (23.1)	25 (43.1)	**<0.001**	**<0.001**

* Chi square was used to calculate p-value

ψ The cutoffs for the various FS intake categories are based on percentage of energy intake, as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

[a] *p* for trend was assessed by logistic regression with adjustment for the same covariates as in the main analysis

E. Odds of not meeting the nutritional requirements at the various free sugar intake cutoffs

The odds of not meeting the NRVs were calculated according to FS intake categories (expressed as 5% increments in energy intakes), for all the investigated nutrients. For this purpose, we have first used C1 as the reference category (EFS <5%) in the regression models and assessed the odds of not meeting the respective NRVs at C2, C3, C4, C5 and C6. The results of these analyses are presented in Tables **16** and **17** in the Appendix 1 for survey 1 and 2 respectively. However, given that participants in C1 had a significantly lower energy intake, which may impact the absolute intakes of micronutrients, we have repeated the same analyses but using C2 as the reference in the regression analyses. Accordingly, the results are presented in Table **10** for children aged 6 months to 5 years and Table **11** for participants aged 5 to 18 years.

Table **10** shows that, in comparison with C2 (5-10% EFS), there were significantly higher odds of not meeting the NRVs at C6 (>25% EFS) for all nutrients except for vitamin C, calcium, magnesium, vitamin D, iron, potassium, and biotin (13/20 nutrients). At C5 (20-25% EFS), there were significantly higher odds of not meeting the NRVs for riboflavin, calcium, phosphorous, vitamin A, vitamin K, pantothenic acid, and selenium (7/20 nutrients). As for children consuming 15-20% EFS (C4), there were also significantly higher odds of not meeting the NRVs for calcium, vitamin A, vitamin K, and pantothenic acid (4/20 nutrients), in comparison with C2. Moreover, children with 10-15% EFS (C3) had significantly higher odds of not meeting the NRVs for vitamin B6, calcium, phosphorous, vitamin K, zinc, and pantothenic acid (6/20 nutrients). Interestingly, FS intake <5% EFS (C1) was associated with higher odds of not meeting the NRVs for all nutrients significance except for vitamin B12, vitamin K, iron, linoleic acid, and alpha linolenic acid. However, in comparison with C2, the odds of not meeting the respective NRVs were lower for vitamin D in the C1 category.

Similarly, Table **11** indicates that in comparison with C2 (5-10% EFS), there were significantly higher odds of not meeting the NRVs at C6 (>25% EFS) for all nutrients, except vitamin C, folate, calcium, vitamin A, and iron (15/20 nutrients). At C5 (20-25% EFS), there were significantly higher odds of not meeting the NRVs for all nutrients except thiamin, vitamin B6, calcium, iron, zinc, biotin, and selenium (13/20 nutrients). As for participants consuming 15-20% energy intake from FS (C4), there were also significantly higher odds of not meeting the NRVs for niacin, vitamin B6, folate, choline, pantothenic acid, and selenium (6/20 nutrients) in comparison to C2. Moreover, children with 10-15% EFS (C3) had significantly higher odds of not meeting the NRVs for vitamin D only. As for participants consuming <5% energy intake from FS (C1), there were significantly higher odds of not meeting the NRVs for niacin, vitamin D, and vitamin A (3/20 nutrients).

Table 10: Odds ratios (95%CI) of not meeting the NRVs according to cutoffs of free sugars intake (5% increment), among 6 months to 4.9 years Lebanese children

Nutrient	**Free sugars intake cutoffs***											
	C2 (ref) n= 227		C1 n= 297		C3 n= 180		C4 n= 93		C5 n= 56		C6 n= 40	
	Cases	OR	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)
Vitamin C	26	1	69	**1.85 (1.10, 3.09)**	22	1.10 (0.60, 2.02)	14	1.51 (0.74, 3.05)	6	0.96 (0.37, 2.48)	6	1.69 (0.64, 4.49)
Thiamin	6	1	36	**3.76 (1.52, 9.31)**	11	2.5 (0.90, 6.93)	4	1.86 (0.51, 6.81)	4	3.04 (0.82, 11.28)	6	**8.56 (2.5, 28.83)**
Riboflavin	3	1	24	**5.54 (1.61, 19.11)**	5	2.16 (0.51, 9.19)	3	2.68 (0.53, 13.56)	7	**10.96 (2.72, 44.15)**	5	**13.01 (2.92, 57.99)**
Niacin	16	1	50	**2.00 (1.09, 3.71)**	17	1.42 (0.70, 2.93)	11	1.96 (0.87, 4.44)	6	1.71 (0.63, 4.62)	12	**7.03 (2.94, 16.78)**
Vitamin B6	11	1	48	**3.07 (1.52, 6.19)**	22	**2.81 (1.32, 5.97)**	9	2.27 (0.90, 5.70)	3	1.16 (0.31, 4.32)	6	**4.10 (1.40, 11.97)**
DFE	53	1	87	**1.81 (1.18, 2.76)**	55	1.44 (0.92, 2.25)	29	1.41 (0.82, 2.43)	16	1.26 (0.65, 2.45)	22	**3.61 (1.79, 7.31)**
Vitamin B12	24	1	40	1.53 (0.87, 2.69)	26	1.42 (0.78, 2.58)	11	1.15 (0.54, 2.46)	10	1.77 (0.79, 3.97)	10	**3.06 (1.31, 7.13)**
Calcium	73	1	107	**2.35 (1.54, 3.58)**	83	**1.90 (1.23, 2.92)**	45	**1.91 (1.13, 3.22)**	30	**2.43 (1.30, 4.55)**	21	2.02 (0.99, 4.14)
Phosphorous	10	1	77	**4.80 (2.37, 9.71)**	21	**3.27 (1.47, 7.25)**	6	1.89 (0.65, 5.48)	6	**3.14 (1.06, 9.32)**	6	**6.29 (2.05, 19.31)**
Magnesium	24	1	97	**2.33 (1.38, 3.92)**	16	0.92 (0.46, 1.84)	10	1.36 (0.60, 3.09)	4	0.78 (0.25, 2.44)	4	1.59 (0.49, 5.12)
Vitamin D	205	1	233	**0.55 (0.32, 0.95)**	170	1.75 (0.80, 3.82)	89	2.17 (0.72, 6.51)	55	5.37 (0.71, 40.93)	39	3.57 (0.46, 27.50)
Vitamin A RE	42	1	104	**2.20 (1.43, 3.37)**	43	1.39 (0.86, 2.25)	31	**2.29 (1.32, 3.97)**	25	**3.60 (1.92, 6.73)**	14	**2.63 (1.26, 5.51)**
Vitamin K	60	1	60	1.05 (0.68, 1.63)	68	**1.71 (1.11, 2.64)**	42	**2.19 (1.31, 3.68)**	23	**1.88 (1.01, 3.51)**	25	**4.11 (1.99, 8.48)**
Iron	29	1	69	1.31 (0.79, 2.17)	21	0.96 (0.52, 1.78)	13	1.33 (0.64, 2.74)	7	1.10 (0.45, 2.73)	6	1.71 (0.64, 4.59)
Zinc	10	1	40	**3.24 (1.54, 6.79)**	17	**2.27 (1.01, 5.09)**	8	2.12 (0.81, 5.58)	5	2.11 (0.69, 6.45)	6	**4.34 (1.46, 12.87)**
Potassium	112	1	197	**2.17 (1.49, 3.15)**	94	1.12 (0.75, 1.65)	50	1.18 (0.73, 1.92)	34	1.56 (0.86, 2.83)	25	1.69 (0.84, 3.39)
Biotin	66	1	119	**1.82 (1.23, 2.68)**	62	1.29 (0.85, 1.97)	37	1.61 (0.97, 2.68)	21	1.52 (0.82, 2.82)	15	1.65 (0.80, 3.38)
Choline	142	1	246	**2.65 (1.73, 4.04)**	116	1.09 (0.73, 1.64)	65	1.42 (0.84, 2.39)	42	1.83 (0.94, 3.55)	33	**2.95 (1.25, 7.01)**
Pantothenic Acid	26	1	52	**3.21 (1.35, 3.95)**	36	**1.95 (1.12, 3.39)**	21	**2.26 (1.19, 4.31)**	22	**4.91 (2.47, 9.74)**	12	**3.42 (1.53, 7.67)**
Selenium	12	1	78	**3.54 (1.92, 6.89)**	16	2.12 (0.95, 4.75)	4	1.12 (0.34, 3.67)	7	**3.56 (1.26, 10.11)**	4	**3.90 (1.11, 13.70)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with aged and sex as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 1 year and intakes lower than the estimated requirement were considered as not meeting the nutritional requirement for children aged 1-5years. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 5 years.

* The cutoffs for the various FS intake categories are based on percentage of EI as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

Table 11: Odds ratios (95%CI) of not meeting the NRVs according to cutoffs of free sugars intake (5% increment), among 5-18 years Lebanese children and adolescents

Nutrient	**Free sugars intake cutoffs***											
	C2 (ref) n= 278		C1 n= 178		C3 n= 282		C4 n= 207		C5 n= 108		C6 n= 58	
	Cases	OR	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)
Vitamin C	94	1	94	1.47 (0.99, 2.20)	109	1.19 (0.83, 1.70)	80	1.15 (0.78, 1.69)	50	**1.70 (1.06, 2.73)**	23	1.21 (0.66, 2.23)
Thiamin	50	1	50	1.32 (0.81, 2.14)	56	1.05 (0.67, 1.64)	50	1.34 (0.84, 2.15)	29	1.60 (0.91, 2.79)	30	**5.05 (2.62, 9.73)**
Riboflavin	71	1	71	1.32 (0.86, 2.05)	81	1.12 (0.76, 1.66)	72	1.47 (0.97, 2.22)	43	**2.01 (1.22, 3.30)**	35	**5.01 (2.66, 9.43)**
Niacin	41	1	41	**1.72 (1.05, 2.82)**	47	1.11 (0.70, 1.78)	53	**2.05 (1.28, 3.28)**	32	**2.49 (1.44, 4.30)**	27	**5.05 (2.66, 9,58)**
Vitamin B6	60	1	60	1.30 (0.83, 2.04)	65	1.03 (0.68, 1.55)	66	**1.65 (1.08, 2.52)**	34	1.63 (0.98, 2.73)	32	**4.34 (2.33, 8.07)**
Folate	153	1	153	0.97 (0.65, 1.45)	164	1.13 (0.80, 1.59)	138	**1.59 (1.08, 2.34)**	75	**1.88 (1.15, 3.08)**	38	1.52 (0.82, 2.81)
Vitamin B12	133	1	133	0.91 (0.62, 1.35)	133	0.94 (0.67, 1.33)	106	1.12 (0.77, 1.62)	68	**1.85 (1.16, 2.95)**	41	**2.62 (1.40, 4.91)**
Calcium	234	1	234	0.83 (0.49, 1.38)	232	0.87 (0.55, 1.36)	174	0.95 (0.58, 1.57)	94	1.25 (0.64, 2.41)	53	1.97 (0.73, 5.30)
Phosphorous	146	1	146	1.12 (0.73, 1.72)	145	0.90 (0.62, 1.30)	121	1.17 (0.78, 1.74)	72	**1.90 (1.14, 3.16)**	42	**2.55 (1.27, 5.10)**
Magnesium	105	1	105	1.37 (0.88, 2.13)	125	1.27 (0.86, 1.87)	99	1.43 (0.94, 2.17)	59	**2.18 (1.30, 3.65)**	39	**4.25 (2.12, 8.53)**
Vitamin D	275	1	275	**1.04 (1.16, 6.58)**	282	**5.2 (4.21, 9.34)**	206	2.48 (0.25, 24.68)	108	**4.3 (1.56, 6.98)**	58	**4.1 (1.34, 7.69)**
Vitamin A	202	1	202	**0.61 (0.40, 0.92)**	204	0.98 (0.67, 1.43)	164	1.37 (0.89, 2.12)	89	**1.77 (1.00, 3.13)**	47	1.65 (0.80, 3.39)
Vitamin K	106	1	106	0.96 (0.65, 1.43)	109	1.03 (0.73, 1.45)	85	1.16 (0.80, 1.68)	55	**1.82 (1.16, 2.88)**	31	**2.0 (1.11, 3.57)**
Iron	50	1	50	1.58 (0.99, 2.50)	59	1.18 (0.78, 1.81)	42	1.17 (0.74, 1.86)	23	1.22 (0.70, 2.14)	17	1.84 (0.95, 3.55)
Zinc	108	1	108	1.01 (0.67, 1.51)	107	0.92 (0.64, 1.31)	98	1.37 (0.93, 2.00)	54	1.54 (0.97, 2.46)	40	**3.50 (1.85, 6.59)**
Potassium	184	1	184	1.50 (0.97, 2.32)	192	1.06 (0.74, 1.53)	152	1.36 (0.91, 2.04)	83	**1.70 (1.00, 2.88)**	49	**2.73 (1.26, 5.90)**
Biotin	136	1	136	1.28 (0.85, 1.92)	158	1.34 (0.94, 1.91)	123	1.42 (0.97, 2.09)	62	1.42 (0.96, 2.53)	49	**5.93 (2.65, 13.27)**
Choline	233	1	233	0.79 (0.47, 1.33)	238	1.02 (0.64, 1.62)	192	**2.45 (1.31, 4.57)**	102	**3.32 (1.36, 8.12)**	56	**5.19 (1.21, 22.34)**
Pantothenic Acid	166	1	166	1.02 (0.68, 1.54)	180	1.15 (0.81, 1.64)	157	**2.11 (1.40, 3.18)**	86	**2.63 (1.53, 4.52)**	51	**4.65 (1.99, 10.86)**
Selenium	35	1	35	1.52 (0.89, 2.60)	38	1.03 (0.62, 1.73)	43	**1.88 (1.12, 3.14)**	25	1.97 (1.08, 3.60)	25	**5.13 (2.60, 10.12)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent
Odds ratio (95%CI) were calculated by logistic regressions, with age, sex, and governorate as covariates
For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the estimated requirement were considered as not meeting the nutritional requirement. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement.
* The cutoffs for the various FS intake categories are based on percentage of EI as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

F. Odds of not meeting nutritional requirements at free sugar intake cutoffs that correspond to the WHO recommendations

In order to assess the associations between adherence to the WHO recommended cutoffs and micronutrient intakes, we have conducted further analyses using logistic regression to examine the odds of not meeting NRVs at FS intake levels ≥5% of energy (i.e., C2 to C6) compared to <5%. The same was done for EFS ≥ 10% (i.e., C3 to C6), in comparison with <10% EFS (C1 and C2). The results of these analyses are presented in Tables **18** and **19** in Appendix **1** for survey 1 and 2 respectively. However, given that participants in C1 had a significantly lower energy intake, which may impact the absolute intakes of micronutrients, we have repeated the same analyses but with additional adjustment for total energy intake. The results are presented in Table **12** and Table **13** for children aged 6 months to 5 years and those aged 5 to 18 years respectively.

For children aged 6 months to 5 years, when using <5% EFS as the reference group, a significant increase in the odds of not meeting the nutritional requirements with ≥5% EFS was observed for vitamin D, vitamin K, iron, and pantothenic acid. When using <10% EFS as the reference group, those with ≥10% EFS had significant increase in the odds of not meeting the nutritional requirements for 10 nutrients including niacin, vitamin B6, folate, vitamin B12, calcium, phosphorous, vitamin D, vitamin A, vitamin K, zinc, and pantothenic acid.

For children aged 5 to 18 years, when using <5% EFS as the reference group, a significant increase in the odds of not meeting the nutritional requirements with ≥5% EFS was observed for all nutrients expect vitamin C, vitamin D, iron, potassium, magnesium, and selenium. When using <10% EFS as the reference group, those with ≥10% EFS had significant increase in the odds of not meeting the nutritional requirements for all nutrients except vitamin C, phosphorous, vitamin D, iron, and potassium.

In line with the approach adopted by Wong et al (2019), we have also examined the cutoff of 20% EFS as follows: ≥ 20% EFS (C5 and C6) in comparison with <20% EFS (C1 to C4). In under-five children, the results showed that that those with ≥20% EFS had significantly higher odds of not meeting the nutritional requirements for half the nutrients tested, compared with <20% EFS. For older children and adolescents (survey 2), the results showed that those with ≥20% EFS had significantly higher odds of not meeting the nutritional requirements for all nutrients except vitamin C, folate, and iron compared with <20% EFS.

Table 12: Odds ratios (95%CI) of not meeting the NRVs according to the WHO free sugar cutoffs and according to the 20% cutoff in Lebanese children aged 6 months to 4.9 years with energy intake adjustments

Nutrients	**Fee sugar cutoffs**											
	<5% (ref) n=297		**≥ 5%** n=596		**<10% (ref)** n=456		**≥ 10%** n=655		**<20% (ref)** n=797		**≥ 20%** n=96	
	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)
Vitamin C	69	1	74	0.91 (0.59, 1.39)	95	1	48	1.04 (0.68, 1.60)	131	1	12	0.93 (0.47, 1.85)
Thiamin	36	1	31	1.15 (0.58, 2.30)	42	1	25	1.81 (0.89, 3.67)	57	1	10	**3.91 (1.42, 10.79)**
Riboflavin	24	1	23	0.96 (0.46, 2.01)	27	1	20	1.81 (0.88, 3.73)	35	1	12	**7.42 (2.92, 18.83)**
Niacin	50	1	62	1.54 (0.92, 2.59)	66	1	46	**2.02 (1.20, 3.39)**	94	1	18	**3.31 (1.62, 6.75)**
Vitamin B6	48	1	51	1.29 (0.72, 2.32)	59	1	40	**2.12 (1.17, 3.83)**	90	1	9	1.03 (0.39, 2.69)
Folate	87	1	175	1.12 (0.77, 1.63)	140	1	122	**1.47 (1.05, 2.06)**	224	1	38	1.54 (0.93, 2.52)
Vitamin B12	40	1	81	1.06 (0.67, 1.68)	64	1	57	1.36 (0.90, 2.05)	101	1	20	**1.77 (1.01, 3.09)**
Calcium	107	1	252	0.91 (0.63, 1.30)	180	1	179	**1.58 (1.15, 2.18)**	308	1	51	1.36 (0.84, 2.22)
Phosphorous	77	1	49	0.84 (0.48, 1.49)	87	1	39	**1.89 (1.02, 3.50)**	114	1	12	**2.60 (1.01, 6.78)**
Magnesium	97	1	58	0.82 (0.49, 1.38)	121	1	34	0.77 (0.43, 1.36)	147	1	8	0.75 (0.28, 2.01)
Vitamin D	233	1	558	**4.68 (2.77, 7.89)**	438	1	353	**4.02 (2.22, 7.29)**	697	1	94	**5.42 (1.27, 23.07)**
Vitamin A	104	1	155	0.94 (0.66, 1.33)	146	1	113	**1.53 (1.10, 2.12)**	220	1	39	**2.13 (1.33, 3.40)**
Vitamin K	60	1	218	**2.07 (1.42, 3.02)**	120	1	158	**2.38 (1.72, 3.28)**	230	1	48	**2.04 (1.28, 3.25)**
Iron	69	1	76	**1.61 (1.01, 2.58)**	98	1	47	1.35 (0.84, 2.17)	132	1	13	1.35 (0.65, 2.79)
Zinc	40	1	46	1.01 (0.57, 1.80)	50	1	36	**1.65 (1.43, 2.90)**	75	1	11	1.61 (0.69, 3.72)
Potassium	197	1	315	0.89 (0.61, 1.28)	309	1	203	1.13 (0.81, 1.58)	453	1	59	1.31 (0.78, 2.19)
Biotin	119	1	201	0.84 (0.60, 1.16)	185	1	135	1.17 (0.87, 1.58)	284	1	36	1.17 (0.74, 1.85)
Choline	246	1	398	0.68 (0.46, 1.02)	388	1	256	1.09 (0.78, 1.54)	569	1	75	1.67 (0.96, 2.91)
Pantothenic Acid	52	1	117	**1.64 (1.02, 2.62)**	78	1	91	**2.88 (1.85, 4.49)**	135	1	34	**3.82 (2.07, 7.02)**
Selenium	78	1	43	0.87 (0.50, 1.52)	90	1	31	1.40 (0.76, 2.60)	110	1	11	**2.92 (1.13, 7.56)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with age, sex, and energy intake as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 1 year and intakes lower than the estimated requirement were considered as not meeting the nutritional requirement for children aged 1-5years. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 5 years.

Table 13: Odds ratios (95%CI) of not meeting the NRVs according to the WHO free sugar cutoffs and according to the 20% cutoff in Lebanese participants aged 5-18 years with energy intake adjustments

Nutrients	**Fee sugar cutoffs**											
	<5% (ref) n=178		**≥ 5%** n=933		**<10% (ref)** n=456		**≥ 10%** n=655		**<20% (ref)** n=945		**≥ 20%** n=166	
	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)
Vitamin C	82	1	356	0.99 (0.69, 1.43)	176	1	262	1.13 (0.87, 1.48)	365	1	73	1.13 (0.78, 1.64)
Thiamin	48	1	215	**1.87 (1.16, 3.02)**	98	1	165	**1.62 (1.12, 2.33)**	204	1	59	**1.95 (1.22, 3.11)**
Riboflavin	61	1	302	**1.85 (1.20, 2.87)**	132	1	231	**1.75 (1.26, 2.42)**	285	1	78	**2.20 (1.43, 3.37)**
Niacin	44	1	200	**1.67 (1.04, 2.70)**	85	1	159	**1.93 (1.33, 2.81)**	185	1	59	**2.13 (1.33, 3.41)**
Vitamin B6	53	1	257	**1.98 (1.25, 3.12)**	113	1	197	**1.72 (1.22, 2.42)**	244	1	66	**1.75 (1.12, 2.73)**
Folate	102	1	568	**1.90 (1.29, 2.80)**	255	1	415	**1.58 (1.19, 2.09)**	557	1	113	1.39 (0.93, 2.08)
Vitamin B12	85	1	481	**1.51 (1.06, 2.13)**	218	1	348	**1.30 (1.01, 1.68)**	457	1	109	**1.97 (1.37, 2.85)**
Calcium	147	1	787	**1.01 (1.01, 1.02)**	381	1	553	**1.02 (1.01, 1.03)**	787	1	147	**1.02 (1.01, 1.03)**
Phosphorous	107	1	526	**1.69 (1.06, 2.71)**	253	1	380	1.28 (0.92, 1.77)	519	1	114	**2.03 (1.27, 3.26)**
Magnesium	90	1	427	**2.17 (1.29, 3.65)**	195	1	322	**1.91 (1.33, 2.74)**	419	1	98	**2.28 (1.41, 3.70)**
Vitamin D	176	1	929	2.52 (0.45, 9.26)	451	1	654	7.21 (0.83, 8.47)	939	1	166	**8.98 (3.45, 9.65)**
Vitamin A	113	1	706	**2.32 (1.61, 3.35)**	315	1	504	**1.58 (1.19, 2.09)**	683	1	136	**1.72 (1.11, 2.67)**
Vitamin K	66	1	386	**1.57 (1.09, 2.24)**	172	1	280	**1.35 (1.04, 1.75)**	366	1	86	**1.66 (1.16, 2.38)**
Iron	47	1	191	1.21 (0.77, 1.93)	97	1	141	1.14 (0.80, 1.64)	198	1	40	0.70 (0.42, 1.15)
Zinc	76	1	407	**2.30 (1.50, 3.53)**	184	1	299	**1.53 (1.12, 2.07)**	389	1	94	**1.85 (1.21, 2.83)**
Potassium	136	1	660	1.21 (0.74, 1.97)	320	1	476	1.30 (0.93, 1.83)	664	1	132	**1.68 (1.01, 2.79)**
Biotin	103	1	528	1.32 (0.91, 1.92)	239	1	392	**1.50 (1.15, 1.97)**	520	1	111	**1.68 (1.13, 2.51)**
Choline	147	1	821	**2.29 (1.42, 3.70)**	380	1	588	**1.96 (1.35, 2.87)**	810	1	158	**3.16 (1.48, 6.75)**
Pantothenic Acid	114	1	640	**2.69 (1.74, 4.17)**	280	1	474	**2.26 (1.64, 3.11)**	617	1	137	**2.78 (1.67, 4.63)**
Selenium	38	1	166	1.63 (1.00, 2.68)	73	1	131	**1.74 (1.18, 2.56)**	154	1	50	**1.96 (1.22, 3.14)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with age, sex, governorate, and energy intake as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the estimated requirement were considered as not meeting the nutritional requirement. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement.

CHAPTER V

DISCUSSION

Accumulating evidence shows that a high intake of sugar, specifically FS, may be associated with overweight, obesity, poor nutritional status, metabolic syndrome, dental caries and NCDs among children and adolescents (WHO, 2019). Hence the importance of examining FS intake and its nutritional/health outcomes in this age group.

The results of this study documented an association between FS intake and the dilution of micronutrient intakes in Lebanese children and adolescents. It was evident that as the consumption of FS increased, micronutrient intakes decreased, and these decreases were significant for most nutrients, specifically vitamin D, vitamin A, calcium, iron, folate, and zinc which also happen to be the nutrients of concern in children and adolescents in Lebanon (Hwalla et al, 2017). A review assessing the nutritional status and dietary intakes of children in the Eastern Mediterranean region identified a triple burden of malnutrition in this age group- underweight, overweight/obesity and micronutrient inadequacies (Nasreddine, Kassis, Ayoub, Naja, & Hwalla, 2018). In Lebanon, 35%, 73%-88%, 84%-95% of school aged children do not meet two third of the recommended RDA for iron, calcium, and vitamin D respectively (Nasreddine et al, 2018; DRI, 2005; Salamoun et al, 2005). Moreover, a study showed that 77% of 6–19-year-old Lebanese children and adolescents do not meet two thirds of the RDA for calcium (Nasreddine et al, 2020). It also showed that 36% and 27% of this age group do not meet two third the RDA for iron and zinc respectively. In addition, the study indicated that 55.3% of these Lebanese children and adolescents do not reach two third the

RDA requirements for vitamin A and 23 % to 26% of them do not meet two third the RDA for vitamins E and C. Micronutrients are crucial cornerstones of dietary quality, and their inadequacies may have major deleterious impacts on children and adolescent's health (Mullie et al, 2018). They are responsible for a variety of functions, including enabling the body to produce enzymes, hormones and other substances needed for normal growth and development (WHO, n.d.). According to UNICEF (2018), millions of children suffer from cognitive delays, stunted growth, weakened immunity and disease as a result of micronutrient deficiencies.

In our analysis of micronutrient intakes across the various categories of FS intake based on 5% energy increments (C1-C6), the absolute intakes of micronutrients were the highest and proportions of subjects not meeting the NRVs were the lowest, when the percent energy intake from FS was between 5% and 10%, which is also within the cutoff suggested by the WHO. In contrast, an excessive intake of FS, especially more than 20% energy intake, was associated with significantly lower micronutrient intakes and a higher proportion of subjects not meeting the NRVs. Interestingly, our results showed that participants within the lowest FS intake category (below 5% of energy intake) had lower absolute intakes of several micronutrients, and higher proportions of subjects not meeting the NRVs, especially in children aged 6 months to 5 years. These findings are possibly due to the lower intake of total energy at this intake level (C1), which may have had a direct impact on the absolute intake of micronutrients. However, when analyzing micronutrient intakes expressed in 1000 kcal (micronutrient density), which typically adjusts for energy intake, the highest micronutrient intakes were observed in children and adolescents consuming <5% EFS, followed by the ones having 5-10% EFS, which are also within the cutoff suggested by the WHO. Moreover, the results showed that subjects with an excessive FS intake, typically more than 20% EFS, had the lowest micronutrient density values.

Similar observations of an inverse relationship between micronutrient intake and FS consumption were made in previous studies conducted amongst children and adolescents in different countries (Wong et al, 2019; Gibson et al 2016; Alexy et al, 2003; Joyce & Gibney, 2008; Fulgoni et al 2019; Overby et al, 2004; Fujiwara et al, 2021). A study on children and adolescents participating in the UK National Diet and Nutrition Survey 2008-2012, reported a significant nutrient dilution that occurred at intakes >13% EFS (Gibson et al, 2016). This is somehow similar to what was observed in our study, where micronutrients intakes significantly decreased when %EFS exceeded >10%. Also, a study on Japanese children and adolescents observed significantly reduced intakes for 22 micronutrients in the EFS category ≥10% compared to lower ones (Fujiwara et al, 2021). Moreover, a study conducted by Wong et al. (2019) on Australian children, found that participants with FS intake of ≥20% EFS had significantly greater odds of having inadequate intakes of more than half of the micronutrients examined in the study, which is also in line with our findings. In the US, a cross-sectional study based on dietary data from NHANES 2009-2014 observed an intake threshold, whereby added sugars intakes above 19% of energy intake were associated with significant inadequacies in the intakes of magnesium, calcium, and vitamin D (Fulgoni et al, 2019).

The inverse association between FS consumption and micronutrient intakes may be explained by the fact that the main source of FS in the diet is discretionary foods that are often nutrient-depleted. A recent study conducted in Lebanon by Jomaa et. al (2020), showed that the main contributor of FS in the diet of children and adolescents included syrups, sweetened beverages, biscuits, and chocolates. Of concern, the study highlighted that sugar sweetened beverages, including carbonated soft drinks and sweetened fruit juices, were the highest contributors to FS in the diet of children and adolescents, an observation that appears to be unique to the Lebanese setting. On the other hand, the results of this study showed that fresh fruit juice had a minimal contribution to FS intake in both age groups, being estimated at 0.9-1.9% in under five children and less than 1% in school-aged children and adolescents. Additionally, previous studies identified several food groups to be common major sources of FS or added sugar in children and adolescents including confectionary, sugar sweetened beverages and sweetened food products (Wong et al, 2019; Alexy et al, 2003; Sluik, Maillot & Moreno, 2017). A cross-sectional study conducted on Japanese children and adolescents showed that FS intake was positively associated with the intakes of sugars and jams, confectioneries, fruit and vegetable juices, and soft drinks, while being inversely associated with the intake of grains, potatoes, pulses, nuts, vegetables, meats, dairy products, fat, and oils (Fujiwara et al, 2021). Additionally, a study conducted on Norwegian children and adolescents found a significant decrease in nutrient-bearing food groups, including fruits and vegetables, with increasing consumption of added sugar (Overby et al. 2004).

After categorizing FS intake based on the WHO cutoffs (conditional recommendation <5% vs >5%; recommendation of <10% vs >10%), and after further adjustment for total energy intake, our results showed that participants consuming <5% EFS and <10% EFS had significantly higher odds of meeting the requirements for most of the investigated nutrients. Thus, our study findings support the hypothesis that the WHO cutoffs of <5% EFS or <10% EFS are suitable for preventing micronutrient dilution. Our results are in line with those reported by another study conducted among Japanese children and adolescents, using data from the 2016 National Health and Nutrition Survey, (Fujiwara et al, 2021), where the intakes of all examined micronutrients were significantly lower in the ≥10% EFS category, (except for vitamin A and C; (22/24 micronutrient), compared with lower EFS intake. Moreover, the mean intake of 14 micronutrients were significantly lower in the 5%-10% EFS category compared with lower intake levels. Thus, the study suggested that the WHO recommendations might help prevent nutrient dilution in Japanese children and adolescents. However, our results are in disagreement with those reported by another study conducted on Australian children and adolescents, where those whose FS intake was within the WHO cutoff of <10% EFS did not have significantly better micronutrient intake than others (Wong et al, 2019).

A. Strengths and limitations

This study has several notable strengths. First, it is the first analysis that addresses the relationship between FS intake and micronutrient dilution among children and adolescents aged 6 months to 18 years in Lebanon and the Eastern Mediterranean Region. Second, the study was conducted using national food surveys carried out on nationally representative samples of children and adolescents. Also, in both surveys, similar methods were adopted in data collection, dietary assessment, and analysis.

On the other hand, the study's findings should be interpreted while considering the following limitations. First, like other studies where dietary intake was assessed by means of self-reporting, dietary assessment may be prone to reporting errors. Underreporting of food intake may lead to underestimation of nutrient intakes. For instance, due to social desirability bias, subjects may be more likely to underreport foods high in FS and over-report healthy foods such as fruits and vegetables. Nevertheless, this bias was reduced through the proper training of data collectors. Second, dietary information was assessed based on the collection of one 24-hour recall, which relies on memory and may not be representative of the usual dietary intake at the individual level (Baranowski, 2012). However, this limitation was minimized by using the USDA multiple pass five step approach (Moshfegh, Borrud, & LaComb, 1999). The steps consisted of the following: 1) quick food list recall, 2) forgotten food list probe 3) time and occasion at which foods were consumed, 4) detailed overall cycle and 5) final probe review of the foods consumed. Finally, since there is a lack of local food composition databases, mixed and traditional Lebanese dishes were added to the Nutritionist Pro software using single food items.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

In conclusion, a significant association between FS intake and the dilution of micronutrient intake was observed in Lebanese children and adolescents. Also, our findings showed that the FS recommendations set by the WHO of <5% EFS or <10% EFS had a positive impact on micronutrient adequacy. This study is the first to provide this evidence among children and adolescents in Lebanon and the Eastern Mediterranean Region in general.

Taken together, our findings emphasize the need for nutrition education interventions to improve micronutrient intake, diet quality and overall health among Lebanese children and adolescents. These interventions should mainly focus on the top contributors to FS intake in Lebanese children and adolescents. Of concern, according to our previous study on FS intake in Lebanon (Jomaa et al, 2020), the highest contributor to FS intake is sugar sweetened beverages in both under five children and school aged children and adolescents, an observation that appears to be unique to the Lebanese setting. Thus, the results highlight the need for the development of evidence-based educational sessions for caregivers that increase their awareness about the highest FS contributors, the negative health effects of high FS consumption among their children and improve their knowledge on healthy food choices that are nutrient dense. Moreover, implementation of school-based programs can be done to increase nutritional knowledge among children and adolescents and decrease the intake of foods and drinks high in FS such as sugar sweetened beverages, biscuits, and other desserts.

For school-aged children and adolescents, peer led nutrition education approaches can be implemented as peer acceptance is valued and peer interactions exert a powerful social influence on behavior change in this age group. Finally, effective governmental policies should be developed to control all forms of marketing of foods and beverages high in FS that target children in Lebanon.

APPENDIX

TABLES

Table 14a: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 6 months to 4.9 years

Nutrient	6m-5y (n=893)							
	Daily intake		**Nutrient density/1000 kcal**		**DRI compliance (%)**			
	Median	**Mean ± SE**	**Median**	**Mean ± SE**	**<EAR**	**≥AI**	**<AMDR**	**>AMDR**
Energy (kcal/d)	1290.2	1346.7 ± 18.5	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	53.8	59.3 ± 0.9	44.1	43.9 ± 0.3	**	77.0	**	**
Saturated fat (g/d)	16.8	18.9 ± 0.3	13.8	14.3 ± 0.2	**	**	**	**
Cholesterol (mg/d)	91.1	127.2 ± 4.2	74.3	95.0 ± 2.8	**	**	**	**
MUFA (g/d)	17.6	20.5 ± 0.4	14.9	15.0 ± 0.2	**	**	**	**
PUFA (g/d)	10.6	12.2 ± 0.3	8.7	8.9 ± 0.1	**	**	**	**
Linoleic acid (g/d)	9.9	11.4 ± 0.26	8.1	8.2 ± 0.1	**	68.9	**	**
Alpha linolenic acid(g/d)	0.7	0.8 ± 0.01	0.6	0.6 ± 0.008	**	50.5	**	**
DHA (g/d)	0.0	0.02 ± 0.005	0.0	0.01 ± 0.003	**	**	**	**
Carbohydrate (g/d)	158.6	164.8 ± 2.4	122.3	123.0 ± 0.7	13.6	52.0	**	**
Total Sugar (g/d)	69.7	74.7 ± 1.2	57.9	59.3 ± 0.8	**	**	**	**
Added Sugars (g/d)	18.8	27.4 ± 1.0	14.4	18.7 ± 0.6	**	**	**	**
Free Sugars (g/d)	28.0	35.8 ± 1.1	21.0	24.2 ± 0.7	**	**	**	**
Protein (g/d)	39.2	42.5 ± 0.8	29.9	31.2 ± 0.3	2.1	**	**	**
Dietary fiber (g/d)	8.0	9.3 ± 0.2	6.0	6.7 ± 0.1	**	0.0	**	**
Total Fat (%)	39.6	39.5 ± 0.3	**	**	**	**	10.6	89.4
Saturated fat (%)	12.4	12.8 ± 0.2	**	**	**	**	77.7	22.3
Carbohydrate (%)	48.9	49.2 ± 0.3	**	**	**	**	31.5	68.5
Total Sugar (%)	23.1	23.7 ± 0.3	**	**	**	**	**	**
Added Sugar (%)	5.8	7.5 ± 0.2	**	**	**	**	**	**
Free Sugar (%)	8.4	9.7 ± 0.3	**	**	**	**	**	**
Protein (%)	12.0	12.5 ± 0.1	**	**	**	**	4.0	96.0
Micronutrients								
Vitamin C (mg/d)	55.7	71.6 ± 2.0	49.3	55.6 ± 1.3	10.1	54.1	**	**

Thiamin (mg/d)	0.9	1.0 ± 0.02	0.8	0.7 ± 0.008	5.5	82.4	**	**
Riboflavin (mg/d)	1.1	1.2 ± 0.02	0.9	0.9 ± 0.1	3.5	85.8	**	**
Niacin (mg/d)	10.2	11.4 ± 0.2	8.3	8.4 ± 0.1	10.1	75.0	**	**
Vitamin B-6 (mg/d)	0.8	0.9 ± 0.02	0.6	0.7 ± 0.009	9.1	79.1	**	**
Folate (µg DFE/d)	172.9	207.0 ± 5.1	143.0	158.8 ± 3.1	31.3	80.4	**	**
Vitamin B-12 (µg/d)	1.8	2.5 ± 0.1	1.5	1.9 ± 0.07	12.9	83.1	**	**
Calcium (mg/d)	558.5	631.3 ± 11.7	466.2	499.6 ± 8.2	46.4	91.2	**	**
Phosphorus (mg/d)	677.0	735.5 ± 13.3	498.2	546.0 ± 6.8	10.7	68.9	**	**
Magnesium (mg/d)	141.0	151.0 ± 2.8	108.0	109.8 ± 1.2	8.5	37.8	**	**
Vitamin D (µg/d)	3.8	4.8 ± 0.1	3.0	4.2 ± 0.1	90.6	21.6	**	**
Vitamin A (µg RE/d)	348.7	416.5 ± 15.6	269.1	352.6 ± 10.8	21.6	33.8	**	**
Vitamin K (µg/d)	45.6	67.4 ± 2.8	37.8	51.0 ± 2.0	**	68.9	**	**
Iron (mg/d)	7.8	8.7 ± 0.2	5.9	6.7 ± 1.4	16.2	**	**	**
Zinc (mg/d)	5.6	6.1 ± 0.1	4.5	4.6 ± 0.06	9.6	**	**	**
Sodium (mg/d)	1211.0	1375 ± 30.3	931.3	978.5 ± 15.1	**	75.6	**	**
Potassium (mg/d)	1649.3	1782 ± 29.6	1269.3	1332.7 ± 13.9	**	42.7	**	**
Biotin (µg)	10.4	13.7 ± 0.5	8.6	10.5 ± 0.3	**	62.8	**	**
Choline (mg)	150.0	173.8 ± 3.4	117.2	133.7 ± 2.1	**	27.9	**	**
Pantothenic Acid (mg)	3.1	3.3 ± 0.05	2.5	2.6 ± 0.03	**	81.1	**	**
Selenium (µg)	42.6	49.5 ± 1.2	32.8	36.0 ± 0.6	6.2	49.3	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range
** not available

Table 14b: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 6 months to 4.9 years

Nutrient	**6m-2y (n=370)**							
	Daily intake		**Nutrient density/1000 kcal**		**DRI compliance (%)**			
	Median	**Mean ± SE**	**Median**	**Mean ± SE**	**<EAR**	**≥AI**	**<AMDR**	**>AMDR**
Energy (kcal/d)	985.2	1083 ± 24.1	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	43.8	48.7 ± 1.2	45.3	45.4 ± 0.4	**	77.0	**	**
Saturated fat (g/d)	13.5	15.2 ± 0.4	14.2	14.5 ± 0.3	**	**	**	**
Cholesterol (mg/d)	58.0	79.8 ± 4.1	50.4	76.8 ± 3.7	**	**	**	**
MUFA(g/d)	14.0	16.1 ± 0.4	15.1	15.0 ± 0.2	**	**	**	**
PUFA (g/d)	9.3	10.4 ± 0.3	9.4	9.4 ± 0.2	**	**	**	**
Linoleic acid (g/d)	8.5	9.7 ± 0.3	8.6	8.7 ± 0.2	**	70.0	**	**
Alpha linolenic acid(g/d)	0.7	0.7 ± 0.2	0.7	0.7 ± 0.01	**	57.0	**	**
DHA (g/d)	0.0	0.005 ± 0.0009	0.0	0.046 ± 0.00072	**	**	**	**
Carbohydrate (g/d)	122.6	134.1 ± 3.1	122.9	123.6 ± 1.0	21.2	52.0	**	**
Total Sugar (g/d)	68.5	72.8 ± 1.6	70.4	70.7 ± 1.1	**	**	**	**
Added Sugars (g/d)	6.5	15.9 ± 1.1	7.3	12.9 ± 0.8	**	**	**	**
Free Sugars (g/d)	9.7	18.6 ± 1.2	9.2	15.0 ± 0.8	**	**	**	**
Protein (g/d)	26.0	29.6 ± 0.9	25.2	26.7 ± 0.4	3.5	**	**	**
Dietary fiber (g/d)	5.1	6.2 ± 0.3	4.8	5.4 ± 0.2	**	0.0	**	**
Total Fat (%)	40.8	40.8 ± 0.4	**	**	**	**	10.8	89.2
Saturated fat (%)	12.8	13.1 ± 0.2	**	**	**	**	**	**
Carbohydrate (%)	49.1	49.4 ± 0.4	**	**	**	**	27.5	72.5
Total Sugar (%)	28.2	28.3 ± 0.4	**	**	**	**	**	**
Added Sugar (%)	3.0	5.2 ± 0.3	**	**	**	**	**	**
Free Sugar (%)	3.7	6.0 ± 0.3	**	**	**	**	**	**
Protein (%)	10.1	10.7 ± 0.2	**	**	**	**	0.0	100.0
Micronutrients								
Vitamin C (mg/d)	57.8	66.6 ± 2.2	61.4	64.4 ± 1.8	5.4	54.1	**	**
Thiamin (mg/d)	0.8	0.9 ± 0.2	0.9	0.8 ± 0.01	5.9	82.4	**	**
Riboflavin (mg/d)	1.0	1.1 ± 0.03	1.0	1.0 ± 0.02	2.7	85.8	**	**
Niacin (mg/d)	8.9	9.7± 0.3	9.1	8.8 ± 0.2	8.6	75.0	**	**
Vitamin B-6 (mg/d)	0.7	0.7 ± 0.02	0.6	0.7 ± 0.02	11.7	79.1	**	**
Folate (µg DFE/d)	173.8	204.5 ± 7.6	179.6	187.3 ± 4.4	40.0	80.4	**	**
Vitamin B-12 (µg/d)	1.5	2.0 ± 0.2	1.5	1.7 ± 0.1	12.2	83.1	**	**
Calcium (mg/d)	517.5	559.6 ± 13.7	520.0	542.5 ± 10.9	47.2	91.2	**	**

Phosphorus (mg/d)	454.0	495.9 ± 14.1	425.3	457.3 ± 8.1	23.0	68.9	**	**
Magnesium (mg/d)	90.7	102.0 ± 3.1	87.4	91.7 ± 1.5	14.9	37.8	**	**
Vitamin D (µg/d)	5.8	6.1± 0.2	5.7	6.1 ± 0.2	84.7	21.6	**	**
Vitamin A (µg RAE/d)	456.3	524.2 ± 23.0	488.3	515.7 ± 15.6	10.8	33.8	**	**
Vitamin K (µg/d)	45.5	59.9 ± 4.4	45.3	53.7 ± 3.4	**	84.6	**	**
Iron (mg/d)	8.3	8.8 ± 0.3	8.5	8.2 ± 0.2	23.5	**	**	**
Zinc (mg/d)	5.0	5.3 ± 0.1	5.0	5.0 ± 0.08	12.7	**	**	**
Sodium (mg/d)	713.1	869.5 ± 33.5	714.2	755.6 ± 20.2	**	58.4	**	**
Potassium (mg/d)	1199.7	1307.0 ± 34.5	1148.3	1213.0 ± 18.5	**	35.7	**	**
Biotin (µg)	7.4	10.6 ± 0.7	8.1	10.0 ± 0.5	**	54.0	**	**
Choline (mg)	122.6	138.0 ± 3.9	117.4	132.2 ± 2.8	**	18.1	**	**
Pantothenic Acid (mg)	3.1	3.2 ± 0.7	3.1	3.1 ± 0.4	**	83.8	**	**
Selenium (µg)	28.6	35.5 ± 1.2	28.6	31.8 ± 0.7	10.4	49.3	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range

** not available

Table 14c: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 6 months to 4.9 years

Nutrient	**2-5y (n=523)**							
	Daily intake		**Nutrient density/1000 calories**		**DRI compliance (%)**			
	Median	**Mean ± SE**	**Median**	**Mean ± SE**	**<EAR**	**≥AI**	**<AMDR**	**>AMDR**
Energy (kcal/d)	1507.5	1533.2± 23.5	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	63.8	66.7 ± 1.3	43.3	42.9 ± 0.4	**	**	**	**
Saturated fat (g/d)	19.7	21.5 ± 0.5	13.6	14.1 ± 0.2	**	**	**	**
Cholesterol (mg/d)	127.2	160.7 ± 6.2	84.6	107.8 ± 4.0	**	**	**	**
MUFA (g/d)	21.5	23.7 ± 0.6	14.6	15.1 ± 0.2	**	**	**	**
PUFA (g/d)	11.6	13.4 ± 0.4	8.1	8.3 ± 0.2	**	**	**	**
Linoleic acid (g/d)	11.2	12.7 ± 0.4	7.7	7.9 ± 0.2	**	68.1	**	**
Alpha linolenic acid(g/d)	0.7	0.8 ± 0.02	0.5	0.5 ± 0.01	**	45.9	**	**
DHA (g/d)	0.0	0.3 ± 0.007	0.0	0.02 ± 0.004	**	**	**	**
Carbohydrate (g/d)	180.6	186.0 ± 3.1	122.1	122.6 ± 1.0	10.3	**	**	**
Total Sugar (g/d)	70.1	76.2 ± 1.7	48.5	51.1 ± 0.9	**	**	**	**
Added Sugars (g/d)	26.9	35.5 ± 1.4	18.9	22.8 ± 0.8	**	**	**	**
Free Sugars (g/d)	39.2	47.4 ± 1.6	27.1	30.7 ± 0.9	**	**	**	**
Protein (g/d)	48.0	51.7 ± 1.0	32.8	34.3 ± 0.5	1.2	**	**	1**
Dietary fiber (g/d)	10.2	11.5 ± 0.3	6.8	7.6 ± 0.2	**	0.0	**	**
Total Fat (%)	39.0	38.6 ± 0.4	**	**	**	**	10.5	89.5
Saturated fat (%)	12.2	12.7 ± 0.2	**	**	**	**	77.7	22.3
Carbohydrate (%)	48.9	49.1 ± 0.4	**	**	**	**	33.3	66.7
Total Sugar (%)	19.4	20.5 ± 0.4	**	**	**	**	**	**
Added Sugar (%)	7.6	9.1 ± 0.3	**	**	**	**	**	**
Free Sugar (%)	10.8	12.3 ± 0.3	**	**	**	**	**	**
Protein (%)	13.1	13.7 ± 0.2	**	**	**	**	5.7	94.3
Micronutrients								
Vitamin C (mg/d)	52.1	75.2 ± 3.0	36.5	49.3 ± 1.8	12.0	**	**	**
Thiamin (mg/d)	1.0	1.1 ± 0.02	0.7	0.7 ± 0.01	5.4	**	**	**
Riboflavin (mg/d)	1.2	1.3 ± 0.02	0.8	0.9 ± 0.02	3.8	**	**	**
Niacin (mg/d)	11.2	12.6 ± 0.3	7.8	8.3 ± 0.2	10.7	**	**	**
Vitamin B-6 (mg/d)	1.0	1.0 ± 0.02	0.7	0.7 ± 0.01	8.0	**	**	**
Folate (µg DFE/d)	170.7	208.7 ± 6.8	117.1	138.5 ± 4.0	20.3	**	**	**
Vitamin B-12 (µg/d)	2.2	2.9 ± 0.2	1.6	2.0 ± 0.1	13.2	**	**	**

Calcium (mg/d)	618.5	682.0 ± 17.1	412.7	469.3 ± 11.5	44.6	**	**	**
Phosphorus (mg/d)	858.2	905.0 ± 17.0	578.0	608.7 ± 9.1	5.5	**	**	**
Magnesium (mg/d)	173.4	185.6 ± 3.5	118.3	122.5 ± 1.5	5.7	**	**	**
Vitamin D (µg/d)	3.0	3.8 ± 0.2	80.0	111.3 ± 5.1	93.1	**	**	**
Vitamin A (µg RAE/d)	266.9	340.4 ± 20.5	181.6	237.2 ± 12.5	26.2	**	**	**
Vitamin K (µg/d)	45.7	72.7 ± 3.6	29.6	49.1 ± 2.4	**	57.7	**	**
Iron (mg/d)	7.3	8.6 ± 0.3	4.8	5.6 ± 0.2	11.1	**	**	**
Zinc (mg/d)	6.0	6.6 ± 0.1	4.1	4.4 ± 0.07	7.5	**	**	**
Sodium (mg/d)	1567.0	1733.7 ± 39.1	1093.5	1136.2 ± 18.6	**	87.8	**	**
Potassium (mg/d)	2015.8	2118.6 ± 38.0	1370.6	1417.3 ± 19.0	**	47.6	**	**
Biotin (µg)	12.7	15.7 ± 0.6	8.8	10.9 ± 0.4	**	68.8	**	**
Choline (mg)	180.9	199.1 ± 4.9	117.2	134.6 ± 3.0	**	34.8	**	**
Pantothenic Acid (mg)	3.2	3.3 ± 0.07	2.1	2.2 ± 0.04	**	79.2	**	**
Selenium (µg)	52.6	59.4 ± 1.7	36.1	39.0 ± 0.8	4.4	**	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range

** not available

Table 15a: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 5-18years

Nutrient	5-18y (n=1111)							
	Daily intake		Nutrient density/1000 calories		DRI compliance (%)			
	Median	Mean ± SE	Median	Mean ± SE	<EAR	≥AI	<AMDR	>AMDR
Energy (kcal/d)	11744.9	1888.8 ± 26.0	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	77.6	84.8 ± 1.4	44.4	43.8 ± 0.30	**	**	**	**
Saturated fat (g/d)	19.1	22.1 ± 0.43	10.7	11.5 ± 0.15	**	**	**	**
Cholesterol (mg/d)	108.4	159.3 ± 5.7	59.8	89.3 ± 3.3	**	**	**	**
MUFA (g/d)	27.4	31.1 ± 0.62	15.4	15.9 ± 0.20	**	**	**	**
PUFA(g/d)	16.2	19.3 ± 0.43	9.5	9.8 ± 0.14	**	**	**	**
Linoleic acid (g/d)	15.1	18.1 ± 0.41	8.7	9.2 ± 0.14	**	65.1	**	**
Alpha linolenic acid(g/d)	0.9	1.1 ± 0.022	0.5	0.56 ± 0.0075	**	40.3	**	**
DHA (g/d)	0.0	0.035 ± 0.011	0.0	0.018 ± 0.0043	**	**	**	**
Carbohydrate (g/d)	214.0	229.3 ± 3.3	122.8	123.2 ± 0.73	14.0	**	**	**
Total Sugar (g/d)	69.3	77.8 ± 1.5	40.6	42.0 ± 0.61	**	**	**	**
Added Sugars (g/d)	42.8	52.4 ± 1.3	25.0	27.3 ± 0.55	**	**	**	**
Free Sugars (g/d)	49.1	58.7 ± 1.4	29.0	31.1 ± 0.56	**	**	**	**
Protein (g/d)	50.9	57.6 ± 0.96	28.9	31.4 ± 0.37	0.0	**	**	1**
Dietary fiber (g/d)	12.8	14.9 ± 0.28	7.2	8.0 ± 0.11	**	8.1	**	**
Total Fat (%)	39.9	39.4 ± 0.27	**	**	**	**	7.0	93.0
Saturated fat (%)	9.7	10.4 ± 0.14	**	**	**	**	33.3	66.7
Carbohydrate (%)	49.1	49.3 ± 0.29	**	**	**	**	32.0	68.0
Total Sugar (%)	16.2	16.8 ± 0.24	**	**	**	**	**	**
Added Sugar (%)	10.0	10.9 ± 0.22	**	**	**	**	**	**
Free Sugar (%)	11.6	12.4 ± 0.22	**	**	**	**	**	**
Protein (%)	11.6	12.5 ± 0.15	**	**	**	**	32.9	67.1
Micronutrients								
Vitamin C (mg/d)	49.4	72.7 ± 2.2	27.6	41.0 ± 1.3	39.4	**	**	**
Thiamin (mg/d)	1.1	1.2 ± 0.19	0.6	0.65 ± 0.0074	23.7	**	**	**
Riboflavin (mg/d)	1.1	1.2 ± 0.23	0.6	0.64 ± 0.013	32.7	**	**	**
Niacin (mg/d)	14.1	18.0 ± 1.2	7.9	10.0 ± 0.89	22.0	**	**	**
Vitamin B-6 (mg/d)	1.1	1.3 ± 0.025	0.6	0.68 ± 0.01	27.9	**	**	**
Folate (µg DFE /d)	202.7	248.2 ± 5.7	114.9	136.4 ± 2.7	60.3	**	**	**
Vitamin B-12 (µg/d)	1.4	2.6 ± 0.22	0.8	1.4 ± 0.12	50.9	**	**	**

Calcium (mg/d)	548.4	637.8 ± 12.1	313.3	355.9 ± 6.0	84.1	**	**	**
Phosphorus (mg/d)	759.5	832.2 ± 12.8	435.0	452.9 ± 4.3	57.0	**	**	**
Magnesium (mg/d)	202.6	225.9 ± 3.9	115.9	123.1 ± 1.2	99.2	**	**	**
Vitamin D (µg/d)	0.3	1.3 ± 0.094	0.2	0.74 ± 0.057	99.5	**	**	**
Vitamin A (µg RAE/d)	225.2	367.9 ± 22.5	124.3	209.9 ± 12.5	73.7	**	**	**
Vitamin K (µg/d)	85.9	165.0 ± 7.2	50.8	88.9± 3.7	**	56.9	**	**
Iron (mg/d)	9.2	10.9 ± 0.22	5.2	5.8 ± 0.092	21.4	**	**	**
Zinc (mg/d)	6.6	7.9 ± 0.15	3.7	4.2 ± 0.6	49.3	**	**	**
Sodium (mg/d)	1943.9	2153.5 ± 38.6	1068.9	1162.3 ± 17.2	**	74.9	**	**
Potassium (mg/d)	2005.4	2206.4 ± 36.2	1148.3	1193.8 ± 12.7	**	28.4	**	**
Biotin (µg)	14.7	18.9 ± 0.54	8.4	10.2 ± 0.23	**	40.9	**	**
Choline (mg)	164.3	202.2 ± 4.27	91.6	113.0 ± 2.2	**	12.9	**	**
Pantothenic Acid (mg)	3.0	3.4 ± 0.60	1.7	1.8 ± 0.024	**	32.1	**	**
Selenium (µg)	61.4	70.5 ± 1.3	34.9	38.6 ± 0.59	18.4	**	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range

** not available

Table 15b: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 5-18years

Nutrient	5-10 y (n=421)							
	Daily intake		Nutrient density/1000kcal		DRI compliance (%)			
	Median	Mean ± SE	Median	Mean ± SE	<EAR	≥AI	<AMDR	>AMDR
Energy (kcal/d)	1640.2	1725.3 ± 35.3	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	71.0	76.7 ± 1.9	43.9	43.6 ± 0.47	**	**	**	**
Saturated fat (g/d)	18.0	20.9 ± 0.64	11.4	12.0 ± 0.26	**	**	**	**
Cholesterol (mg/d)	102.7	143.9 ± 9.7	61.5	89.5 ± 6.5	**	**	**	**
MUFA (g/d)	24.8	27.7 ± 0.86	15.1	15.6 ± 0.32	**	**	**	**
PUFA(g/d)	14.6	16.5 ± 0.54	9.0	9.2 ± 0.20	**	**	**	**
Linoleic acid (g/d)	13.9	15.5 ± 0.51	8.4	8.6 ± 0.20	**	63.2	**	**
Alpha linolenic acid(g/d)	0.8	0.93 ± 0.028	0.5	0.53 ± 0.011	**	41.3	**	**
DHA (g/d)	0.0	0.02 ± 0.0032	0.0	0.013 ± 0.0023	**	**	**	**
Carbohydrate (g/d)	202.9	213.5 ± 4.7	124.0	124.7 ± 1.2	11.9	**	**	**
Total Sugar (g/d)	67.3	73.7 ± 2.4	41.2	43.3 ± 1.0	**	**	**	**
Added Sugars (g/d)	38.4	48.1 ± 2.2	25.0	27.4 ± 0.93	**	**	**	**
Free Sugars (g/d)	45.7	54.4 ± 2.2	29.5	31.6 ± 0.92	**	**	**	**
Protein (g/d)	46.5	50.7 ± 1.2	28.4	30.4 ± 0.54	0.0	**	**	1**
Dietary fiber (g/d)	11.9	13.6 ± 0.41	7.2	7.9 ± 0.17	**	8.3	**	**
Total Fat (%)	39.5	39.2 ± 0.42	**	**	**	**	6.7	93.3
Saturated fat (%)	10.2	10.8 ± 0.23	**	**	**	**	30.4	69.6
Carbohydrate (%)	49.6	49.9 ± 0.46	**	**	**	**	29.2	70.8
Total Sugar (%)	16.5	17.3 ± 0.4	**	**	**	**	**	**
Added Sugar (%)	10.0	11.0 ± 0.37	**	**	**	**	**	**
Free Sugar (%)	11.8	12.6 ± 0.37	**	**	**	**	**	**
Protein (%)	11.4	12.2 ± 0.22	**	**	**	**	39.5	65.8
Micronutrients								
Vitamin C (mg/d)	44.7	65.7 ± 3.5	26.4	39.6 ± 2.2	29.9	**	**	**
Thiamin (mg/d)	1.0	1.1 ± 0.025	0.6	0.67 ± 0.12	12.1	**	**	**
Riboflavin (mg/d)	1.0	1.1 ± 0.027	0.6	0.65 ± 0.015	19.2	**	**	**
Niacin (mg/d)	12.5	13.9 ± 0.38	7.7	8.2 ± 0.20	15.9	**	**	**
Vitamin B-6 (mg/d)	1.0	1.1 ± 0.030	0.6	0.64 ± 0.014	20.4	**	**	**
Folate (µg DFE /d)	189.8	229.2 ± 8.0	118.4	136.6 ± 4.3	47.7	**	**	**
Vitamin B-12 (µg/d)	1.4	1.9 ± 0.11	0.9	1.21 ± 0.082	42.0	**	**	**
Calcium (mg/d)	541.5	622.3 ± 18.6	342.7	377.2 ± 10.0	78.9	**	**	**
Phosphorus (mg/d)	719.6	756.2 ± 16.7	432.7	448.6 ± 6.5	31.8	**	**	**

Magnesium (mg/d)	193.0	205.9 ± 4.8	116.2	121.4 ± 1.6	99.2	**	**	**
Vitamin D (µg/d)	0.5	1.3 ± 0.087	0.3	0.84 ± 0.057	99.8	**	**	**
Vitamin A (µg RAE/d)	218.3	311.8 ± 18.7	132.7	193.9 ± 13.8	65.3	**	**	**
Vitamin K (µg/d)	74.3	137.7 ± 10.1	43.9	81.2± 6.1	**	54.9	**	**
Iron (mg/d)	8.9	10.1 ± 0.33	5.4	5.9 ± 0.15	18.3	**	**	**
Zinc (mg/d)	6.2	6.9 ± 0.2	3.8	4.1 ± 0.08	33.7	**	**	**
Sodium (mg/d)	1747.8	1947.2 ± 55.9	1054.3	1157.9 ± 31.0	**	79.8	**	**
Potassium (mg/d)	1876.1	2002.7 ± 49.9	1128.0	1171.6 ± 19.4	**	33.0	**	**
Biotin (µg)	13.9	17.9 ± 0.77	8.4	10.6 ± 0.46	**	51.0	**	**
Choline (mg)	153.1	180.9 ± 5.5	91.3	110.4 ± 3.5	**	16.6	**	**
Pantothenic Acid (mg)	2.9	3.0 ± 0.074	1.7	1.8 ± 0.037	**	39.7	**	**
Selenium (µg)	57.1	64.3 ± 1.7	35.3	39.0 ± 0.91	9.5	**	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range

** not available

Table 15c: Dietary intakes of energy, macro-, and micronutrient intakes of Lebanese children aged 5-18years

Nutrient	10-18y (n=690)							
	Daily intake		Nutrient density/1000 calories		DRI compliance (%)			
	Median	**Mean ± SE**	**Median**	**Mean ± SE**	**<EAR**	**≥AI**	**<AMDR**	**>AMDR**
Energy (kcal/d)	11851.2	1988.5 ± 35.2	**	**	**	**	**	**
Macronutrients								
Total Fat (g/d)	83.4	89.8 ± 1.9	44.8	43.9 ± 0.39	**	**	**	**
Saturated fat (g/d)	20.0	22.9 ± 0.57	10.3	11.2 ± 0.19	**	**	**	**
Cholesterol (mg/d)	115.6	168.7 ± 6.9	58.7	89.2 ± 3.60	**	**	**	**
MUFA (g/d)	29.9	33.1 ± 0.85	15.7	16.1 ± 0.25	**	**	**	**
PUFA(g/d)	17.5	21.0 ± 0.60	9.7	10.1 ± 0.19	**	**	**	**
Linoleic acid (g/d)	16.5	19.7 ± 0.57	9.0	9.5 ± 0.18	**	66.2	**	**
Alpha linolenic acid(g/d)	1.0	1.2 ± 0.03	0.5	0.58 ± 0.00994	**	39.7	**	**
DHA (g/d)	0.0	0.04 ± 0.02	0.0	0.0216 ± 0.0068	**	**	**	**
Carbohydrate (g/d)	222.0	239.0 ± 4.4	121.9	122.3 ± 0.94	**	**	**	**
Total Sugar (g/d)	71.3	80.2 ± 1.96	40.3	41.2 ± 0.75	**	**	**	**
Added Sugars (g/d)	45.7	55.0 ± 2.0	25.1	27.3 ± 0.68	**	**	**	**
Free Sugars (g/d)	52.2	61.3 ± 1.7	28.7	30.7 ± 0.70	**	**	**	**
Protein (g/d)	54.7	61.8 ± 1.3	29.1	31.9 ± 0.50	**	**	**	1**
Dietary fiber (g/d)	13.5	15.7 ± 0.37	7.2	8.1 ± 0.15	**	7.8	**	**
Total Fat (%)	40.4	39.5 ± 0.35	**	**	**	**	7.2	92.8
Saturated fat (%)	9.3	10.1 ± 0.17	**	**	**	**	35.1	64.9
Carbohydrate (%)	48.7	48.9 ± 0.38	**	**	**	**	33.8	66.2
Total Sugar (%)	16.1	16.5 ± 0.30	**	**	**	**	**	**
Added Sugar (%)	10.0	10.9 ± 0.28	**	**	**	**	**	**
Free Sugar (%)	11.5	12.3 ± 0.28	**	**	**	**	**	**
Protein (%)	11.7	12.8 ± 0.20	**	**	**	**	32.0	68.0
Micronutrients								
Vitamin C (mg/d)	52.9	77.0 ± 3.0	28.8	41.9 ± 1.6	45.2	**	**	**
Thiamin (mg/d)	1.1	1.2 ± 0.026	0.6	0.64 ± 0.0095	30.7	**	**	**
Riboflavin (mg/d)	1.0	1.1 ± 0.034	0.6	0.63 ± 0.02	40.9	**	**	**
Niacin (mg/d)	15.2	20.5 ± 2.0	8.2	11.1 ± 1.4	25.7	**	**	**
Vitamin B-6 (mg/d)	1.2	1.4 ± 9.04	0.6	0.70 ± 0.01	32.5	**	**	**
Folate (µg DFE /d)	208.9	259.8 ± 7.7	113.2	136.3 ± 3.4	68.0	**	**	**
Vitamin B-12 (µg/d)	1.4	2.9 ± 0.3	0.8	1.6 ± 0.19	56.4	**	**	**
Calcium (mg/d)	553.5	647.3 ± 15.9	299.8	342.9 ± 7.4	87.2	**	**	**

Phosphorus (mg/d)	783.6	878.6 ± 17.6	437.2	455.5 ± 5.7	72.3	**	**	**
Magnesium (mg/d)	212.0	238.1± 5.5	115.9	124.2 ± 1.7	99.2	**	**	**
Vitamin D (µg/d)	0.3	1.2 ± 0.1	0.1	0.70 ± 0.085	99.3	**	**	**
Vitamin A (µg RAE/d)	228.6	402.1 ± 34.3	119.0	219.7 ± 18.3	78.8	**	**	**
Vitamin K (µg/d)	94.7	181.6 ± 9.9	52.9	93.6 ± 4.7	**	58.1	**	**
Iron (mg/d)	9.4	11.4 ± 0.23	5.1	5.8 ± 0.12	23.3	**	**	**
Zinc (mg/d)	7.1	8.4 ± 0.2	3.8	4.3 ± 0.09	58.8	**	**	**
Sodium (mg/d)	2031.1	2279.3 ± 51.4	1083.4	1164.9 ± 20.1	**	71.9	**	**
Potassium (mg/d)	2097.2	2330.6± 49.2	1159.7	1207.3 ± 16.7	**	25.5	**	**
Biotin (µg)	14.8	19.5 ± 0.73	8.4	9.9 ± 0.3	**	34.7	**	**
Choline (mg)	172.3	215.3 ± 6.0	91.7	114.7 ± 2.9	**	10.6	**	**
Pantothenic Acid (mg)	3.1	3.6 ± 0.84	1.7	1.9 ± 0.032	**	27.5	**	**
Selenium (µg)	64.9	74.3 ± 1.9	34.7	38.4 ± 0.77	23.8	**	**	**

MUFA monounsaturated fatty acid, *PUFA* polyunsaturated fatty acid, *DFE* dietary folate equivalent, *RE* retinol equivalent, *EAR* estimated average requirement, *AI* adequate intake, *AMDR* acceptable macronutrient distribution range

** not available

Table 16: Odds ratios (95%CI) of not meeting the NRVs according to cutoffs of free sugars intake, among 6months to 4.9 years Lebanese children (C1 as reference)

Nutrient	**Free sugars intake cutoffs***											
	C1 (ref) n= 297		C2 n= 227		C3 n= 180		C4 n= 93		C5 n= 56		C6 n= 40	
	Cases	OR	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)
Vitamin C	69	1	26	**0.54 (0.32, 0.90)**	22	0.59 (0.34, 1.03)	14	0.81 (0.42, 1.58)	6	0.52 (0.21, 1.30)	6	0.92 (0.36, 2.36)
Thiamin	36	1	6	**0.27 (0.11, 0.66)**	11	0.66 (0.32, 1.40)	4	0.50 (0.17, 1.49)	4	0.80 (0.27, 2.47)	6	2.27 (0.82, 6.28)
Riboflavin	24	1	3	**0.18 (0.05, 0.62)**	5	0.39 (0.14, 1.08)	3	0.48 (0.14, 1.72)	7	1.98 (0.76, 5.15)	5	2.35 (0.77, 7.14)
Niacin	50	1	16	**0.50 (0.27, 0.92)**	17	0.71 (0.38, 1.32)	11	0.98 (0.47, 2.05)	6	0.85 (0.34, 2.16)	12	**3.50 (1.56, 7.87)**
Vitamin B6	48	1	11	**0.33 (0.16, 0.66)**	22	0.92 (0.51, 1.64)	9	0.74 (0.34, 1.63)	3	0.38 (0.11, 1.29)	6	1.33 (0.51, 3.52)
DFE	87	1	53	**0.55 (0.36, 0.85)**	55	0.80 (0.52, 1.22)	29	0.78 (0.46, 1.33)	16	0.70 (0.36, 1.35)	22	2.00 (0.99, 4.02)
Vitamin B12	40	1	24	0.65 (0.37, 1.15)	26	0.93 (0.53, 1.63)	11	0.75 (0.36, 1.57)	10	1.15 (0.53, 2.53)	10	2.00 (0.87, 4.58)
Calcium	107	1	73	**0.43 (0.28, 0.65)**	83	0.81 (0.53, 1.23)	45	0.81 (0.49, 1.37)	30	1.03 (0.55, 1.92)	21	0.86 (0.42, 1.76)
Phosphorous	77	1	10	**0.21 (0.10, 0.42)**	21	0.68 (0.39, 1.20)	6	**0.40 (0.16, 0.98)**	6	0.66 (0.26, 1.67)	6	1.31 (0.49, 3.50)
Magnesium	97	1	24	**0.43 (0.26, 0.72)**	16	**0.40 (0.22, 0.73)**	10	0.59 (0.28, 1.25)	4	0.34 (0.11, 1.01)	4	0.68 (0.22, 2.12)
Vitamin D	233	1	205	**1.83 (1.06, 3.17)**	170	**3.20 (1.55, 6.60)**	89	**3.96 (1.36, 11.52)**	55	**9.82 (1.31, 13.43)**	39	6.52 (0.86, 9.23)
Vitamin A RE	104	1	42	**0.46 (0.30, 0.70)**	43	**0.63 (0.41, 0.98)**	31	1.04 (0.62, 1.75)	25	1.64 (0.90, 2.99)	14	1.20 (0.58, 2.46)
Vitamin K	60	1	60	0.95 (0.61, 1.47)	68	**1.62 (1.05, 2.51)**	42	**2.08 (1.23, 3.51)**	23	1.78 (0.95, 3.35)	25	**3.90 (1.88, 8.09)**
Iron	69	1	29	0.76 (0.46, 1.26)	21	0.73 (0.42, 1.29)	13	1.01 (0.51, 2.03)	7	0.84 (0.35, 2.03)	6	1.31 (0.50, 3.44)
Zinc	40	1	10	**0.31 (0.15, 0.65)**	17	0.70 (0.37, 1.32)	8	0.66 (0.29, 1.51)	5	0.65 (0.24, 1.78)	6	1.34 (0.51, 3.56)
Potassium	197	1	112	**0.46 (0.32, 0.67)**	94	**0.52 (0.35, 0.77)**	50	**0.55 (0.33, 0.89)**	34	0.72 (0.39, 1.32)	25	0.78 (0.39, 1.58)
Biotin	119	1	66	**0.55 (0.37, 0.81)**	62	**0.71 (0.47, 1.07)**	37	0.89 (0.54, 1.46)	21	0.84 (0.45, 1.54)	15	0.91 (0.44, 1.85)
Choline	246	1	142	**0.38 (0.25, 0.58)**	116	**0.41 (0.26, 0.64)**	65	**0.54 (0.31, 0.93)**	42	0.69 (0.35, 1.38)	33	1.12 (0.46, 2.71)
Pantothenic Acid	52	1	26	**0.43 (0.25, 0.74)**	36	0.85 (0.51, 1.39)	21	0.98 (0.54, 1.79)	22	**2.13 (1.12, 4.04)**	12	1.48 (0.68, 3.22)
Selenium	78	1	12	**0.28 (0.15, 0.55)**	16	0.60 (0.32, 1.13)	4	**0.32 (0.11, 0.93)**	7	1.01 (0.35, 3.52)	4	**0.93 (0.91, 0.95)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with aged and sex as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 1 year and intakes lower than the estimated requirement were considered as not meeting the nutritional requirement for children aged 1-5years. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 5 years.

*Percentage of total energy intake from FS of each cutoff are as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

Table 17: Odds ratios (95%CI) of not the NRVs according to cutoffs of free sugars intake, among 5-18 years Lebanese participants (C1 as reference)

Nutrient	**Free sugars intake cutoffs***											
	C1 (ref) n= 178		C2 n= 278		C3 n= 282		C4 n= 207		C5 n= 108		C6 n= 58	
	Cases	OR	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)	Cases	OR (95%CI)
Vitamin C	94	1	94	0.68 (0.45, 1.02)	109	0.81 (0.54, 1.20)	80	0.78 (0.51, 1.19)	50	1.16 (0.70, 1.90)	23	0.82 (0.44, 1.55)
Thiamin	50	1	50	0.76(0.47, 1.23)	56	0.79 (0.49, 1.28)	50	1.02 (0.62, 1.68)	29	1.21 (0.68, 2.16)	30	**3.93 (1.95, 7.53)**
Riboflavin	71	1	71	0.76 (0.49, 1.17)	81	0.85 (0.55, 1.31)	72	1.11 (0.70, 1.74)	43	1.51 (0.86, 2.56)	35	**3.78 (1.97, 7.28)**
Niacin	41	1	41	**0.58 (0.36, 0.95)**	47	0.64 (0.40, 1.04)	53	1.19 (0.73, 1.92)	32	1.44 (0.83, 2.52)	27	**2.93 (1.54, 5.60)**
Vitamin B6	60	1	60	0.77 (0.49, 1.20)	65	0.79 (0.51, 1.23)	66	1.27 (0.81, 2.00)	34	1.26 (0.73, 2.15)	32	**3.34 (1.76, 6.33)**
Folate	153	1	153	1.03 (0.69, 1.53)	164	1.16 (0.78, 1.72)	138	**1.63 (1.06, 2.52)**	75	**1.94 (1.15, 3.28)**	38	1.56 (0.82, 2.97)
Vitamin B12	133	1	133	1.09 (0.74, 1.62)	133	1.03 (0.70, 1.52)	106	1.23 (0.81, 1.86)	68	**2.02 (1.22, 3.34)**	41	**2.86 (1.49, 5.51)**
Calcium	234	1	234	1.21 (0.72, 2.03)	232	1.05 (0.64, 1.75)	174	1.16 (0.67, 1.99)	94	1.51 (0.75, 3.03)	53	2.39 (0.87, 6.58)
Phosphorous	146	1	146	0.89 (0.58, 1.37)	145	0.80 (0.52, 1.23)	121	1.04 (0.66, 1.64)	72	1.69 (0.97, 2.94)	42	**2.27 (1.10, 4.68)**
Magnesium	105	1	105	0.73 (0.47, 1.14)	125	0.93 (0.60, 1.44)	99	1.04 (0.665, 1.67)	59	1.59 (0.91, 2.77)	39	**3.10 (1.50, 6.42)**
Vitamin D	275	1	275	0.96 (0.15, 6.10)	282	17.43 (0.10, 19.65)	206	2.39 (0.21, 9.98)	108	19.67 (0.02, 21.35)	58	18.84 (0.01, 22.68)
Vitamin A	202	1	202	**1.65 (1.09, 2.50)**	204	**1.62 (1.07, 2.44)**	164	**2.27 (1.43, 3.60)**	89	**2.93 (1.62, 5.29)**	47	**2.72 (1.31, 5.69)**
Vitamin K	106	1	106	1.04 (0.70, 1.54)	109	1.07 (0.72, 1.58)	85	1.20 (0.79, 1.82)	55	**1.90 (1.16, 3.10)**	31	**2.07 (1.13, 3.81)**
Iron	50	1	50	0.63 (0.40, 1.01)	59	0.75 (0.48, 1.17)	42	0.74 (0.46, 1.20)	23	0.78 (0.44, 1.38)	17	1.17 (0.60, 2.27)
Zinc	108	1	108	0.99 (0.66, 1.49)	107	0.91 (0.61, 1.36)	98	1.36 (0.89, 2.08)	54	1.53 (0.92, 2.53)	40	**3.47 (1.79, 6.73)**
Potassium	184	1	184	0.67 (0.43, 1.04)	192	0.71 (0.46, 1.10)	152	0.91 (0.56, 1.46)	83	1.14 (0.64, 2.03)	49	1.82 (0.81, 4.09)
Biotin	136	1	136	0.78 (0.52, 1.17)	158	1.05 (0.70, 1.57)	123	1.11 (0.72, 1.72)	62	1.22 (0.72, 2.05)	49	**4.64 (2.03, 10.62)**
Choline	233	1	233	1.26 (0.75, 2.12)	238	1.28 (0.76, 2.16)	192	**3.09 (1.58, 6.02)**	102	**4.19 (1.66, 10.54)**	56	**6.54 (1.49, 28.67)**
Pantothenic Acid	166	1	166	0.98 (0.65, 1.47)	180	1.13 (0.75, 1.70)	157	**2.06 (1.30, 3.27)**	86	**2.57 (1.44, 4.58)**	51	**4.54 (1.90, 10.88)**
Selenium	35	1	35	0.66 (0.39, 1.12)	38	0.68 (0.40, 1.15)	43	1.23 (0.73, 2.09)	25	1.29 (0.70, 2.39)	25	**3.37 (1.69, 6.69)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent
Odds ratio (95%CI) were calculated by logistic regressions, with age, sex, and governorate as covariates
For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the estimated requirement were considered as not meeting the nutritional requirement. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement.
*Percentage of total energy intake from FS of each cutoff are as follows: C1: <5%, C2: 5% to <10%, C3: 10% to <15%, C4: 15% to <20%, C5: 20 to 25%, C6: >25%

Table 18: Odds ratios (95%CI) of not meeting the NRVs according to the WHO free sugar cutoffs and according to the 20% cutoff in Lebanese participants aged 6months to 4.9 years

Nutrients	**Fee sugar cutoffs**											
	<5% (ref) n=178		**≥ 5%** n=933		**<10% (ref)** n=456		**≥ 10%** n=655		**<20% (ref)** n=945		**≥ 20%** n=166	
	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)
Vitamin C	69	1	74	**0.61 (0.41, 0.91)**	95	1	48	0.86 (0.58, 1.28)	131	1	12	0.91 (0.48, 1.74)
Thiamin	36	1	31	**0.54 (0.31, 0.95)**	42	1	25	1.17 (0.67, 2.02)	57	1	10	**2.10 (1.01, 4.40)**
Riboflavin	24	1	23	0.53 (0.27, 1.02)	27	1	20	1.31 (0.70, 2.46)	35	1	12	**4.02 (1.94, 8.34)**
Niacin	50	1	62	0.76 (0.49, 1.19)	66	1	46	1.30 (0.84, 1.99)	94	1	18	**2.24 (1.25, 3.99)**
Vitamin B6	48	1	51	**0.61 (0.38, 0.96)**	59	1	40	1.23 (0.78, 1.93)	90	1	9	0.99 (0.47, 2.07)
Folate	87	1	175	0.73 (0.52, 1.03)	140	1	122	1.15 (0.85, 1.56)	224	1	38	1.46 (0.93, 2.28)
Vitamin B12	40	1	81	0.86 (0.55, 1.34)	64	1	57	1.23 (0.82, 1.84)	101	1	20	**1.76 (1.02, 3.03)**
Calcium	107	1	252	**0.66 (0.47, 0.93)**	180	1	179	1.29 (0.96, 1.73)	308	1	51	1.35 (0.87, 2.11)
Phosphorous	77	1	49	**0.44 (0.28, 0.68)**	87	1	39	1.04 (0.67, 1.63)	114	1	12	1.47 (0.74, 2.92)
Magnesium	97	1	58	**0.44 (0.29, 0.66)**	121	1	34	**0.61 (0.39, 0.96)**	147	1	8	0.72 (0.33, 1.59)
Vitamin D	233	1	558	**2.69 (1.67, 4.32)**	438	1	353	**3.11 (1.76, 5.53)**	697	1	94	**4.77 (1.15, 9.66)**
Vitamin A	104	1	155	**0.69 (0.50, 0.97)**	146	1	113	1.28 (0.94, 1.74)	220	1	39	**2.01 (1.29, 3.14)**
Vitamin K	60	1	218	**1.49 (1.05, 2.13)**	120	1	158	**1.98 (1.46, 2.68)**	230	1	48	**1.97 (1.27, 3.07)**
Iron	69	1	76	0.82 (0.54, 1.22)	98	1	47	0.96 (0.64, 1.45)	132	1	13	1.17 (0.62, 2.22)
Zinc	40	1	46	**0.56 (0.34, 0.91)**	50	1	36	1.15 (0.71, 1.84)	75	1	11	1.39 (0.70, 2.75)
Potassium	197	1	315	**0.52 (0.38, 0.72)**	309	1	203	1.05 (0.79, 1.41)	453	1	59	1.23 (0.79, 1.91)
Biotin	119	1	201	**0.69 (0.49, 0.94)**	185	1	135	0.89 (0.65, 1.21)	284	1	36	1.15 (0.73, 1.80)
Choline	246	1	398	**0.45 (0.31, 0.65)**	388	1	256	0.89 (0.66, 1.21)	569	1	75	1.61 (0.96, 2.69)
Pantothenic Acid	52	1	117	0.82 (0.55, 1.22)	78	1	91	**1.62 (1.14, 2.29)**	135	1	34	**2.43 (1.52, 3.88)**
Selenium	78	1	43	**0.46 (0.29, 0.72)**	90	1	31	0.90 (0.56, 1.47)	110	1	11	1.72 (0.83, 3.59)

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with age and sex as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 1 year and intakes lower than the estimated requirement were considered as not meeting the nutritional requirement for children aged 1-5years. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement for children aged 6 months to 5 years.

Table 19: Odds ratios (95%CI) of not meeting the NRVs according to the WHO free sugar cutoffs and according to the 20% cutoff in Lebanese participants aged 5-18 years

Nutrients	**Fee sugar cutoffs**											
	<5% (ref) n=178		**≥ 5%** n=933		**<10% (ref)** n=456		**≥ 10%** n=655		**<20% (ref)** n=945		**≥ 20%** n=166	
	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)	Cases	OR	Cases	OR (95% CI)
Vitamin C	82	1	356	0.80 (0.57, 1.12)	176	1	262	1.07 (0.83, 1.38)	365	1	73	1.29 (0.91, 1.83)
Thiamin	48	1	215	0.99 (0.67, 1.48)	98	1	165	1.28 (0.94, 1.73)	204	1	59	**2.13 (1.45, 3.13)**
Riboflavin	61	1	302	1.04 (0.73, 1.50)	132	1	231	**1.39 (1.06, 1.82)**	285	1	78	**2.30 (1.61, 3.30)**
Niacin	44	1	200	0.92 (0.62, 1.36)	85	1	159	**1.45 (1.07, 1.97)**	185	1	59	**2.36 (1.62, 3.42)**
Vitamin B6	53	1	257	1.04 (0.72, 1.50)	113	1	197	**1.34 (1.01, 1.77)**	244	1	66	**1.95 (1.36, 2.79)**
Folate	102	1	568	1.30 (0.92, 1.82)	255	1	415	**1.41 (1.09, 1.82)**	557	1	113	**1.53 (1.06, 2.22)**
Vitamin B12	85	1	481	1.26 (0.90, 1.75)	218	1	348	1.25 (0.98, 1.60)	457	1	109	**2.09 (1.47, 2.99)**
Calcium	147	1	787	**1.02 (1.01, 1.03)**	381	1	553	**1.02 (1.01,1.03)**	787	1	147	**1.02 (1.01, 1.03)**
Phosphorous	107	1	526	1.01 (0.70, 1.46)	253	1	380	1.15 (0.88, 1.50)	519	1	114	**2.05 (1.38, 3.03)**
Magnesium	90	1	427	1.02 (0.70, 1.48)	195	1	322	**1.41 (1.07, 1.87)**	419	1	98	**2.20 (1.49, 3.25)**
Vitamin D	176	1	929	2.52 (0.44, 5.26)	451	1	654	7.2 (0.83, 9.45)	939	1	166	8.34 (0.01, 9.99)
Vitamin A	113	1	706	**1.92 (1.35, 2.72)**	315	1	504	**1.52 (1.15, 1.99)**	683	1	136	**1.82 (1.18, 2.79)**
Vitamin K	66	1	386	1.22 (0.87, 1.70)	172	1	280	**1.26 (0.99, 1.62)**	366	1	86	**1.82 (1.30, 2.56)**
Iron	47	1	191	0.74 (0.51, 1.08)	97	1	141	1.02 (0.76, 1.37)	198	1	40	1.19 (0.79, 1.77)
Zinc	76	1	407	1.18 (0.84, 1.66)	184	1	299	1.27 (0.98, 1.64)	389	1	94	**1.93 (1.36, 2.74)**
Potassium	136	1	660	0.81 (0.55, 1.20)	320	1	476	1.15 (0.87, 1.51)	664	1	132	**1.69 (1.12, 2.56)**
Biotin	103	1	528	1.07 (0.75, 1.51)	239	1	392	**1.42 (1.1, 1.83)**	520	1	111	**1.86 (1.27, 2.72)**
Choline	147	1	821	**1.77 (1.13, 2.78)**	380	1	588	**1.82 (1.27, 2.61)**	810	1	158	**3.40 (1.62, 7.15)**
Pantothenic Acid	114	1	640	**1.42 (1.01, 2.02)**	280	1	474	**1.71 (1.31, 2.23)**	617	1	137	**2.55 (1.65, 3.95)**
Selenium	38	1	166	0.98 (0.64, 1.49)	73	1	131	**1.40 (1.01, 1.96)**	154	1	50	**2.21 (1.47, 3.32)**

OR odds ratio, *95%CI* 95% confidence interval, *RE* retinol equivalent, *DFE* dietary folate equivalent

Odds ratio (95%CI) were calculated by logistic regressions, with age, sex, and governorate as covariates

For vitamin C, thiamin, riboflavin, vitamin B6, dietary folate, vitamin B12, calcium, phosphorous, magnesium, vitamin D, vitamin A and selenium intakes lower than the estimated requirement were considered as not meeting the nutritional requirement. For vitamin K, iron, zinc, potassium, biotin, choline, and pantothenic acid intakes lower than the adequate intake were considered not meeting the nutritional requirement.

Table 20: DRI reference intakes

Nutrient	6-12.9m			1-3y			4-8y			9-13y		
	Dietary Reference Intakes			Dietary Reference Intakes			Dietary Reference Intakes			Dietary Reference Intakes		
	EAR/AMDR	AI	UL	EAR/AMDR	AI	UL	EAR/AMDR	AI	UL	EAR/AMDR	AI	UL
Energy (kcal/d)	--	--	--	--	--	--	--	--	--	--	--	--
Macronutrients												
Total Fat (g/d)	--	30	--	--	--	--	--	--	--	--	--	--
Saturated fat (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Cholesterol (mg/d)	--	--	--	--	--	--	--	--	--	--	--	--
MUFA (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
PUFA(g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Linoleic acid (g/d)	--	4.6	--	--	7	--	--	10	--	--	12 (M) – 10 (F)	--
α-linolenic acid(g/d)	--	0.5	--	--	0.7	--	--	0.9	--	--	1.2 (M)- 1.0 (F)	--
DHA (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Carbohydrate (g/d)	--	95	--	100	--	--	100	--	--	100	--	--
Total Sugar (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Added Sugars (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Free Sugars (g/d)	--	--	--	--	--	--	--	--	--	--	--	--
Protein (g/d)	1 g/Kg/d	--	--	0.87 g/Kg	--	--	0.76 g/Kg	--	--	0.76 g/Kg	--	--
Dietary fiber (g/d)	--	--	--	--	19	--	--	25	--	--	31 (M) - 26 (F)	--
Total Fat (%)	--	--	--	30-40%	--	--	25-35%	--	--	25-35%	--	--
Saturated fat (%)	--	--	--	--	--	--	<8%	--	--	<8%	--	--
Carbohydrate (%)	--	--	--	45-65%	--	--	45-65%	--	--	45-65%	--	--
Total Sugar (%)	--	--	--	--	--	--	--	--	--	--	--	--
Added Sugar (%)	--	--	--	--	--	--	--	--	--	--	--	--
Free Sugar (%)	--	--	--	--	--	--	--	--	--	--	--	--
Protein (%)	--	--	--	5-20%	--	--	10-30%	--	--	10-30%	--	--
Micronutrients												
Vitamin C (mg/d)	--	50	--	13	--	400	22	--	650	39	--	1200
Thiamin (mg/d)	--	0.3	--	0.4	--	--	0.5	--	--	0.7	--	--
Riboflavin (mg/d)	--	0.4	--	0.4	--	--	0.5	--	--	0.8	--	--
Niacin (mg/d)	--	4	--	5	--	--	6	--	--	9	--	--
Vitamin B-6 (mg/d)	--	0.3	--	0.4	--	30	0.5	--	40	0.8	--	60
Folate (μg DFE /d)	--	80	--	120	--	--	160	--	--	250	--	--
Vitamin B-12 (μg/d)	--	0.5	--	0.7	--	--	1	--	--	1.5	--	--
Calcium (mg/d)	--	260	1500	500	--	2500	800	--	2500	1100	--	3000
Phosphorus (mg/d)	--	275	--	380	--	3000	405	--	3000	1055	--	4000

Magnesium (mg/d)	--	75	--	65	--	--	110	--	--	200	--	--
Vitamin D (µg/d)	--	10	38	10	--	63	10	--	75	10	--	100
Vitamin A (µg RAE/d)	--	500	600	210	--	600	275	--	900	445 (M)-420 (F)	--	1700
Vitamin K (µg/d)	--	2.5	--	--	30	--	--	55	--	--	60	--
Iron (mg/d)	6.9	--	40	3	--	40	4.1	--	40	5.9 (M) -5.7 (F)	--	40
Zinc (mg/d)	2.5	--	5	2.5	--	7	4	--	12	7	--	23
Sodium (mg/d)	--	110/370	--	--	800	1200	--	1000	1500	--	1200	1800
Potassium (mg/d)	--	400/860	--	--	2000	--	--	2300	--	--	2500 (M) –2300 (F)	--
Biotin (µg)	--	6	--	--	8	--	--	12	--	--	20	--
Choline (mg)	--	150	--	--	200	--	--	250	--	--	375	--
Pantothenic Acid (mg)	--	1.8	--	--	2	--	--	3	--	--	4	--
Selenium (µg)	--	20	60	17	--	90	23	--	150	35	--	280

BIBLIOGRAPHY

Afshin, A., Sur, P. J., Fay, K. A., Cornaby, L., Ferrara, G., Salama, J. S., ... & Murray, C. J. (2019). Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, *393*(10184), 1958-1972.

Al-Daghri, N. M., Al-Othman, A., Alkharfy, K. M., Alokail, M. S., Khan, N., Alfawaz, H. A., ... & Chrousos, G. P. (2012). Assessment of selected nutrients intake and adipocytokines profile among Saudi children and adults. *Endocrine journal*, EJ12-0167.

Al-Jawaldeh, A., Taktouk, M., & Nasreddine, L. (2020). Food consumption patterns and nutrient intakes of children and adolescents in the Eastern Mediterranean Region: A call for policy action. *Nutrients*, *12*(11), 3345.

Al-Musharaf, S., Al-Othman, A., Al-Daghri, N. M., Krishnaswamy, S., Yusuf, D. S., Alkharfy, K. M., ... & Chrousos, G. P. (2012). Vitamin D deficiency and calcium intake in reference to increased body mass index in children and adolescents. *European journal of pediatrics*, *171*(7), 1081-1086.

Al-Rewashdeh, A. Y. A. (2009). Assessment of the nutritional status for preschool children in Jordan. *Bulletin of Faculty of Agriculture, Cairo University*, *60*(4), 423-432.

Alexy, U., Sichert-Hellert, W., & Kersting, M. (2003). Associations between intake of added sugars and intakes of nutrients and food groups in the diets of German children and adolescents. *British journal of nutrition*, *90*(2), 441-447.

Ali, H. I., Ng, S. W., Zaghloul, S., Harrison, G. G., Qazaq, H. S., El Sadig, M., & Yeatts, K. (2013). High proportion of 6 to 18-year-old children and adolescents in the United Arab Emirates are not meeting dietary recommendations. *Nutrition research*, *33*(6), 447-456.

Bassatne, A., Harb, H., Jaafar, B., Romanos, J., Ammar, W., & El-Hajj Fuleihan, G. (2020). Disease burden of osteoporosis and other non-communicable diseases in Lebanon. *Osteoporosis International*, 1-9.

Baranowski, T. (2012). 24-hour recall and diet record methods. *Nutritional epidemiology*, *40*, 49-69.

Camaschella, C. (2019). Iron deficiency. *Blood, The Journal of the American Society of Hematology*, *133*(1), 30-39.

Cohen, D. A., Sturm, R., Lara, M., Gilbert, M., & Gee, S. (2010). Discretionary calorie intake a priority for obesity prevention: results of rapid participatory approaches in low-income US communities. *Journal of public health*, *32*(3), 379-386.

Collison, K. S., Zaidi, M. Z., Subhani, S. N., Al-Rubeaan, K., Shoukri, M., & Al-Mohanna, F. A. (2010). Sugar-sweetened carbonated beverage consumption correlates with BMI, waist circumference, and poor dietary choices in school children. *BMC public health*, *10*(1), 234.

Condon, E., Drilea, S., Jowers, K., Lichtenstein, C., Mabli, J., Madden, E., & Niland, K. (2015). Dietary Guidelines for Americans; US Department of Health and Human Services. *US Department of Agriculture: Washington, DC, USA*.

Corder, K., van Sluijs, E. M., Wright, A., Whincup, P., Wareham, N. J., & Ekelund, U. (2009). Is it possible to assess free-living physical activity and energy expenditure in young people by self-report?. *The American journal of clinical nutrition*, *89*(3), 862-870.

De Onis, M., Blössner, M., & Borghi, E. (2010). Global prevalence and trends of overweight and obesity among preschool children. *The American journal of clinical nutrition*, *92*(5), 1257-1264.

Dinsa, G. D., Goryakin, Y., Fumagalli, E., & Suhrcke, M. (2012). Obesity and socioeconomic status in developing countries: a systematic review. *Obesity reviews*, *13*(11), 1067-1079.

DRI. (2005). Institute of Medicine, Food and Nutrition Board, Dietary Reference Intakes: energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids.

El-Gazzar, H. H., Saleh, S. M., Khairy, S. A., Marei, A. S., ElKelany, K., & Al Soda, M. F. (2019). Relationship between dietary intake and obesity among a group of primary school-aged children in Cairo Governorate. *Journal of Medicine in Scientific Research*, *2*(1), 42.

Erickson, J., & Slavin, J. (2015). Total, added, and free sugars: are restrictive guidelines science-based or achievable?. *Nutrients*, *7*(4), 2866-2878.

Fagt, S., Biltoft-Jensen, A., Matthiessen, J., Groth, M. V., Christensen, T., & Trolle, E. (2008). Dietary habits of Denmark 1995–2006—status and development with focus on fruits, vegetables and added sugar. *Søborg: National Food Institute, Technical University of Denmark*.

FAO. (n.d.). Nutrition country profile: Lebanese Republic. Retrieved November 1, 2020, from http://www.fao.org/3/aq041e/aq041e.pdf

Farajian, P., Risvas, G., Panagiotakos, D. B., & Zampelas, A. (2016). Food sources of free sugars in children's diet and identification of lifestyle patterns associated with free sugars intake: the GRECO (Greek Childhood Obesity) study. *Public health nutrition*, *19*(13), 2326-2335.

Fewtrell, M., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N., Mis, N. F., ... & Molgaard, C. (2017). Complementary feeding: a position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) Committee on Nutrition. *Journal of pediatric gastroenterology and nutrition*, *64*(1), 119-132.

Fidler Mis, N., Braegger, C., Bronsky, J., Campoy, C., Domellöf, M., Embleton, N. D., ... & Mihatsch, W. (2017). Sugar in infants, children and adolescents: a position paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. *Journal of pediatric gastroenterology and nutrition*, *65*(6), 681-696.

Food and Drug Administration, HHS. (2016). Food Labeling: Revision of the Nutrition and Supplement Facts Labels. Final rule. *Federal Register*, *81*(103), 33741.

Fujiwara, A., Okada, E., Okada, C., Matsumoto, M., & Takimoto, H. (2021). Association between free sugar intake and nutrient dilution among Japanese children and adolescents: the 2016 National Health and Nutrition Survey, Japan. *British Journal of Nutrition*, *125*(12), 1394-1404.

Fulgoni III, V. L., Gaine, P. C., Scott, M. O., Ricciuto, L., & DiFrancesco, L. (2019). Association of added sugars intake with micronutrient adequacy in US children and adolescents: NHANES 2009–2014. *Current developments in nutrition*, *3*(12), nzz126.

GBD 2015 Eastern Mediterranean Region Obesity Collaborators. (2018). Burden of obesity in the Eastern Mediterranean Region: findings from the Global Burden of Disease 2015 study. *International journal of public health*, *63*(1), 165-176.

Gibson, S., Francis, L., Newens, K., & Livingstone, B. (2016). Associations between free sugars and nutrient intakes among children and adolescents in the UK. *British Journal of Nutrition*, *116*(7), 1265-1274.

Gidding, S. S., Dennison, B. A., Birch, L. L., Daniels, S. R., Gillman, M. W., Lichtenstein, A. H., Rattay, K. T., Steinberger, J., Stettler, N., Van Horn, L., American Heart Association, & American Academy of Pediatrics (2005). Dietary recommendations for children and adolescents: a guide for practitioners: consensus statement from the American Heart Association. *Circulation*, *112*(13), 2061–2075.

Graham, D. J., & Roberto, C. A. (2016). Evaluating the impact of US Food and Drug Administration–proposed nutrition facts label changes on young adults' visual attention and purchase intentions. *Health Education & Behavior*, *43*(4), 389-398.

Grantham-McGregor, S., & Ani, C. (2001). A review of studies on the effect of iron deficiency on cognitive development in children. *The Journal of nutrition*, *131*(2), 649S-668S.

Guideline, W. H. O. (2019). sugars intake for adults and children. Geneva: World Health Organization, 2015.

Harris, J. L., & Kalnova, S. S. (2018). Food and beverage TV advertising to young children: Measuring exposure and potential impact. *Appetite*, *123*, 49-55.

Herrick, K. A., Fryar, C. D., Hamner, H. C., Park, S., & Ogden, C. L. (2020). Added Sugars Intake among US Infants and Toddlers. *Journal of the Academy of Nutrition and Dietetics*, *120*(1), 23-32.

Hwalla, N., Al Dhaheri, A. S., Radwan, H., Alfawaz, H. A., Fouda, M. A., Al-Daghri, N. M., ... & Blumberg, J. B. (2017). The prevalence of micronutrient deficiencies and inadequacies in the Middle East and approaches to interventions. *Nutrients*, *9*(3), 229.

Jia, P., Stein, A., James, P., Brownson, R. C., Wu, T., Xiao, Q., ... & Wang, Y. (2019). Earth observation: investigating noncommunicable diseases from space. *Annual review of public health*, *40*, 85-104.

Jomaa, L., Hamamji, S., Kharroubi, S., Harake, M. D. E., & Nasreddine, L. (2020). Dietary Intakes, Sources, and Determinants of Total and Free Sugar Consumption Among Lebanese Children and Adolescents: Findings from a National Study. *Current Developments in Nutrition*, *4*(Supplement_2), 1421-1421.

Jomaa, L., Naja, F., Kharroubi, S., & Hwalla, N. (2019). Prevalence and correlates of food insecurity among Lebanese households with children aged 4–18 years: findings from a national cross-sectional study. *Public health nutrition*, *22*(2), 202-211.

Joyce, T., & Gibney, M. J. (2008). The impact of added sugar consumption on overall dietary quality in Irish children and teenagers. *Journal of Human Nutrition and Dietetics*, *21*(5), 438-450.

Kearney, J., Fitzgerald, R., Burnside, G., Higham, S., Flannigan, N., Halford, J. C., & Boyland, E. J. (2020). Television advertisements for high-sugar foods and beverages: effect on children's snack food intake. *British Journal of Nutrition*, 1-7.

Khader, Y. S., Batieha, A., Jaddou, H., Batieha, Z., El-Khateeb, M., & Ajlouni, K. (2011). Metabolic abnormalities associated with obesity in children and adolescents in Jordan. *International journal of pediatric obesity*, *6*(3-4), 215-222.

Khandpur, N., Rimm, E. B., & Moran, A. J. (2020). The influence of the new US Nutrition Facts label on consumer perceptions and understanding of added sugars: a randomized controlled experiment. *Journal of the Academy of Nutrition and Dietetics*, *120*(2), 197-209.

Khawaja, A. H., Qassim, S., Hassan, N. A., & Arafa, E. S. A. (2019). Added sugar: Nutritional knowledge and consumption pattern of a principal driver of obesity and diabetes among undergraduates in UAE. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *13*(4), 2579-2584.

Kibblewhite, R., Nettleton, A., McLean, R., Haszard, J., Fleming, E., Kruimer, D., & Te Morenga, L. (2017). Estimating free and added sugar intakes in New Zealand. *Nutrients*, *9*(12), 1292.

Kyle, T. K., & Thomas, D. M. (2014). Consumers believe nutrition facts labeling for added sugar will be more helpful than confusing. *Obesity*, *22*(12), 2481-2484.

Laquatra, I., Sollid, K., Edge, M. S., Pelzel, J., & Turner, J. (2015). Including "added sugars" on the nutrition facts panel: how consumers perceive the proposed change. *Journal of the Academy of Nutrition and Dietetics*, *115*(11), 1758-1763.

Lei, L., Rangan, A., Flood, V. M., & Louie, J. C. Y. (2016). Dietary intake and food sources of added sugar in the Australian population. *British Journal of Nutrition*, *115*(5), 868-877.

Linseisen, J., Gedrich, K., Karg, G., & Wolfram, G. (2001). Sucrose intake in Germany. *Zeitschrift für Ernährungswissenschaft*, *37*(4), 303-314.

Liu, E., Pimpin, L., Shulkin, M., Kranz, S., Duggan, C. P., Mozaffarian, D., & Fawzi, W. W. (2018). Effect of zinc supplementation on growth outcomes in children under 5 years of age. *Nutrients*, *10*(3), 377.

Louie, J. C. Y., Moshtaghian, H., Boylan, S., Flood, V. M., Rangan, A. M., Barclay, A. W., ... & Gill, T. P. (2015). A systematic methodology to estimate added sugar content of foods. *European journal of clinical nutrition*, *69*(2), 154-161.

Lupton, J. R., Brooks, J., Butte, N. F., Caballero, B., Flatt, J. P., & Fried, S. K. (2002). Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. *National Academy Press: Washington, DC, USA*, *5*, 589-768.

McGuire, S. (2011). US department of agriculture and US department of health and human services, dietary guidelines for Americans, 2010. Washington, DC: US government printing office.

Mela, D. J., & Woolner, E. M. (2018). Perspective: total, added, or free? What kind of sugars should we be talking about?. *Advances in Nutrition*, *9*(2), 63-69.

Mesana, M. I., Hilbig, A., Androutsos, O., Cuenca-Garcia, M., Dallongeville, J., Huybrechts, I., ... & Moreno, L. A. (2018). Dietary sources of sugars in adolescents' diet: the HELENA study. *European journal of nutrition*, *57*(2), 629-641.

Mis, N. F., Kobe, H., & Štimec, M. (2012). Dietary intake of macro-and micronutrients in Slovenian adolescents: comparison with reference values. *Annals of Nutrition and Metabolism*, *61*(4), 305-313.

Moshfegh, A. J., Borrud, L., Perloff, B., & LaComb, R. (1999). Improved method for the 24-hour dietary recall for use in national surveys. *FASEB J*, *13*(4), A603.

Mullie, P., Mertens, E., Charlier, R., Knaeps, S. S., Lefevre, J., & Clarys, P. (2018). Relation between sugar-sweetened beverage consumption and micronutrient intake in a prospective study. *European journal of clinical nutrition*, *72*(1), 170-173.

Mumena, W. A., Alamri, A. A., Mahrous, A. A., Alharbi, B. M., Almohaimeed, J. S., Hakeem, M. I., & Kutbi, H. A. (2020). Knowledge, attitudes, and practices toward added sugar consumption among female undergraduate students in Madinah, Saudi Arabia: A cross-sectional study. *Nutrition*, *79*, 110936.

Naja, F., Itani, L., Kharroubi, S., El Harake, M. D., Hwalla, N., & Jomaa, L. (2020). Food insecurity is associated with lower adherence to the Mediterranean dietary pattern among Lebanese adolescents: a cross-sectional national study. *European journal of nutrition*, *59*(7), 3281-3292.

Nasreddine, L. M., Kassis, A. N., Ayoub, J. J., Naja, F. A., & Hwalla, N. C. (2018). Nutritional status and dietary intakes of children amid the nutrition transition: the case of the Eastern Mediterranean Region. *Nutrition research*, *57*, 12-27.

Nasreddine, L., Chamieh, M. C., Ayoub, J., Hwalla, N., Sibai, A. M., & Naja, F. (2020). Sex disparities in dietary intake across the lifespan: The case of Lebanon. *Nutrition journal*, *19*(1), 1-18.

Nasreddine, L., Hwalla, N., Saliba, A., Akl, C., & Naja, F. (2017). Prevalence and correlates of preschool overweight and obesity amidst the nutrition transition: findings from a national cross-sectional study in Lebanon. *Nutrients*, *9*(3), 266.

Nasreddine, L., Naja, F., Akl, C., Chamieh, M. C., Karam, S., Sibai, A. M., & Hwalla, N. (2014). Dietary, lifestyle and socio-economic correlates of overweight, obesity and central adiposity in Lebanese children and adolescents. *Nutrients*, *6*(3), 1038-1062.

Nasreddine, L., Naja, F., Chamieh, M. C., Adra, N., Sibai, A. M., & Hwalla, N. (2012). Trends in overweight and obesity in Lebanon: evidence from two national cross-sectional surveys (1997 and 2009). *BMC public health*, *12*(1), 1-11.

Nasreddine, L., Naja, F., Sibai, A. M., Helou, K., Adra, N., & Hwalla, N. (2014). Trends in nutritional intakes and nutrition-related cardiovascular disease risk factors in Lebanon: the need for immediate action. *Lebanese Medical Journal*, *103*(1151), 1-9.

Nasreddine, L., Shatila, H., Itani, L., Hwalla, N., Jomaa, L., & Naja, F. (2019). A traditional dietary pattern is associated with lower odds of overweight and obesity among preschool children in Lebanon: a cross-sectional study. *European journal of nutrition*, *58*(1), 91-102.

Newens, K. J., & Walton, J. (2016). A review of sugar consumption from nationally representative dietary surveys across the world. *Journal of human nutrition and dietetics: the official journal of the British Dietetic Association*, *29*(2), 225–240. https://doi.org/10.1111/jhn.12338

Ng, S. W., Zaghloul, S., Ali, H., Harrison, G., Yeatts, K., El Sadig, M., & Popkin, B. M. (2011). Nutrition transition in the United Arab Emirates. *European journal of clinical nutrition*, *65*(12), 1328-1337.

Overby, N. C., Lillegaard, I. T., Johansson, L., & Andersen, L. F. (2004). High intake of added sugar among Norwegian children and adolescents. *Public health nutrition*, *7*(2), 285-293.

Perrar, I., Schmitting, S., Della Corte, K. W., Buyken, A. E., & Alexy, U. (2019). Age and time trends in sugar intake among children and adolescents: Results from the DONALD study. *European Journal of Nutrition*, 1-12.

Pettifor, J. M. (2008). Vitamin D &/or calcium deficiency rickets in infants & children: a global perspective. *Indian Journal of Medical Research*, *127*(3).

Pettifor, J. M., Thandrayen, K., & Thacher, T. D. (2018). Vitamin D deficiency and nutritional rickets in children. In *Vitamin D* (pp. 179-201). Academic Press.

Pivina, L., Semenova, Y., Doşa, M. D., Dauletyarova, M., & Bjørklund, G. (2019). Iron deficiency, cognitive functions, and neurobehavioral disorders in children. *Journal of Molecular Neuroscience*, *68*(1), 1-10.

Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition reviews*, *70*(1), 3-21.

Poti, J. M., Slining, M. M., & Popkin, B. M. (2013). Solid fat and added sugar intake among US children: The role of stores, schools, and fast food, 1994–2010. *American journal of preventive medicine*, *45*(5), 551-559.

Qin, P., Li, Q., Zhao, Y., Chen, Q., Sun, X., Liu, Y., . . . Zhang, M. (2020). Sugar and artificially sweetened beverages and risk of obesity, type 2 diabetes mellitus, hypertension, and all-cause mortality: A dose–response meta-analysis of prospective cohort studies. *European Journal of Epidemiology, 35*(7), 655-671.

Rabenberg, M., & Mensink, G. (2013). Fizzy drinks, juices etc.

Rahim, H. F. A., Sibai, A., Khader, Y., Hwalla, N., Fadhil, I., Alsiyabi, H., ... & Husseini, A. (2014). Non-communicable diseases in the Arab world. *The Lancet*, *383*(9914), 356-367.

Rahman, S. M. M., Hossain, S. M., & Jahan, M. U. (2019). Diet related NCDs: Time for action. *Bangladesh Medical Research Council Bulletin, 45*(3), 131-132.

Rippe, J. M., Sievenpiper, J. L., Lê, K. A., White, J. S., Clemens, R., & Angelopoulos, T. J. (2017). What is the appropriate upper limit for added sugars consumption?. *Nutrition reviews*, *75*(1), 18–36. https://doi.org/10.1093/nutrit/nuw046

SACN, Scientific Advisory Committee on Nutrition. (2015). Carbohydrates and Health. London, Ireland: TSO

Salamoun, M. M., Kizirian, A. S., Tannous, R. I., Nabulsi, M. M., Choucair, M. K., Deeb, M. E., & Fuleihan, G. E. H. (2005). Low calcium and vitamin D intake in healthy children and adolescents and their correlates. *European journal of clinical nutrition*, *59*(2), 177-184.

Schiess, S. A., Grote, V., Scaglioni, S., Luque, V., Martin, F., Stolarczyk, A., ... & Koletzko, B. (2010). Intake of energy providing liquids during the first year of life in five European countries. *Clinical nutrition*, *29*(6), 726-732.

Sibai, A. M., Singh, N. V., Jabbour, S., Saleh, S., Abdulrahim, S., Naja, F., & Yazbek, S. (2017). Does published research on non-communicable disease (NCD) in Arab countries reflect NCD disease burden?. *PLoS One*, *12*(6), e0178401.

Sluik, D., Maillot, M., Kok, F., & Moreno, L. A. (2017). Review of total & added sugar intakes and dietary sources in Europe. *Nutrition journal*.

Stanhope, K. L. (2015;2016;). Sugar consumption, metabolic disease and obesity: The state of the controversy. *Critical Reviews in Clinical Laboratory Sciences, 53*(1), 52-67.

Table, M. (2005). *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids* (Vol. 5, pp. 589-768). National Academy Press: Washington, DC, USA.

UNICEF. (2018). Coverage at a crossroads: new directions for vitamin A supplementation programmes. *New York*.

UNICEF. (2018, June 07). Micronutrients. Retrieved February 05, 2021, from https://sites.unicef.org/nutrition/index_iodine.html

Unicef. (2020,June 25). Noncommunicable diseases. Retrieved October 08, 2020, from https://data.unicef.org/topic/child-health/noncommunicable-diseases/

US Department of Health and Human Services. (2005). Dietary guidelines for Americans 2005. *http://www. health. gov/dietaryguidelines/dga2005/document/default. htm*.

Vanderlee, L., White, C. M., Bordes, I., Hobin, E. P., & Hammond, D. (2015). The efficacy of sugar labeling formats: Implications for labeling policy. *Obesity*, *23*(12), 2406-2413.

Vos, M. B., Kaar, J. L., Welsh, J. A., Van Horn, L. V., Feig, D. I., Anderson, C. A. M., . . . and Council on Hypertension. (2017). Added sugars and cardiovascular disease risk in children: A scientific statement from the american heart association. *Circulation (New York, N.Y.), 135*(19), e1017-e1034.

Willoughby, J. L., & Bowen, C. N. (2014). Zinc deficiency and toxicity in pediatric practice. *Current opinion in pediatrics*, *26*(5), 579-584.

WHO Regional Office for the Eastern Mediterranean. (n.d). "Noncommunicable diseases: STEPwise surveillance". Retrieved November 01, 2020, from http://www.emro.who.int/noncommunicable-diseases/stepwise-surveillance/

Wold Health Organization. (2018, June 1). Noncommunicable diseases. Retrieved from https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

Wong, T. H. T., Mok, A., Ahmad, R., Rangan, A., & Louie, J. C. Y. (2019). Intake of free sugar and micronutrient dilution in Australian children and adolescents. *European journal of nutrition*, *58*(6), 2485-2495.

World Health Organization. (2009). Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency.

World Health Organization, T. (2010). *Global recommendations on physical activity for health*. World Health Organization.

World Health Organization. (2002). *The world health report 2002: reducing risks, promoting healthy life*. World Health Organization.

World Health Organization. (2007). Growth Reference Data for 5-19 Years. Geneva, WHO, 2007.

World Health Organization. (2010). Regional strategy on nutrition 2010- 2019. Regional Committee for the Eastern Mediterranean. Fifty-seventh Session. Retrieved from https://applications.emro.who.int/docs/EM_RC57_4_en.pdf?ua=1&ua=1

World Health Organization. (2013). *Report on the consultation on developing strategic directions for salt and fat reduction in the Eastern Mediterranean Region, Cairo, Egypt, 28–29 November 2012* (No. WHO-EM/NUT/260/E).

World Health Organization. (2015). *Guideline: sugars intake for adults and children*. World Health Organization.

World Health Organization. (2017). Training Course on Child Growth Assessment. Geneva, WHO, 2008.

World Health Organization. (2018). Burden of noncommunicable diseases in the Eastern Mediterranean Region. Retrieved January 24, 2021, from http://www.emro.who.int/noncommunicable-diseases/publications/burden-of-noncommunicable-diseases-in-the-eastern-mediterranean-region.html

World Health Organization. (n.d.). Micronutrients. Retrieved February 05, 2021, from https://www.who.int/health-topics/micronutrients#tab=tab_2

Yeung, C. H., & Louie, J. C. (2019). Methodology for the assessment of added/free sugar intake in epidemiological studies. *Current Opinion in Clinical Nutrition & Metabolic Care*, *22*(4), 271-277.