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Sustainable, Healthy and Affordable Diets for Children in Lebanon: A Call for Action in Dire Times

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Abstract: Achieving sustainable, healthy diets remains a global challenge to meet the sustainable development agenda by 2030. The purpose of this study is to derive optimal dietary recommendations for children that consider nutritional, environmental, and economic parameters of sustainability, using Lebanon as a case study. Data from the latest national food consumption survey conducted among Lebanese children were used. Optimized diets were derived using Optimeal, a software that produces similar patterns to the usual diet while considering nutrition constraints (energy, and macro/micronutrient needs), environmental footprints ((EFPs): water use, energy use, and greenhouse emissions), and cost. Three optimized diets were derived that meet the nutritional needs of children aged 4–8, 9–13, and 14–18 years, while considering EFPs and cost. Compared to the usual intake, optimized diets included higher intake of vegetables, legumes and dairy, and a decrease in saturated oils, processed meats, sugar, salty snacks, sweets, and sugar-sweetened beverages. Overall, the optimized diets decreased cost by 20% and reduced water use, energy use, and GHG emissions, by 20%, 11%, and 22%, respectively. The proposed models consider various constraints and provide sustainable solutions for decision makers within a country undergoing crises.

Keywords: sustainable diet; diet optimization; children; healthy diet; environment footprint; cost; food security; Lebanon

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1. Introduction

Food insecurity remains one of the major challenges facing our world's population. According to the World Food Summit (1996), "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [1]. In 2020, the COVID-19 pandemic disrupted the food systems and adversely affected the food and nutrition security of populations worldwide. According to the latest State of Food and Nutrition Security report, nearly one in three people in the world did not have access to adequate food in 2020, and 12% percent of the global population was severely food insecure. In the Middle East and North Africa (MENA), one of the most volatile and politically unstable regions of the world, the prevalence of food insecurity in 2021 reached 29.2%, making it also one of the most food-insecure regions in the world [2]. In parallel, the population of the MENA region is on the rise and it is projected to incur a 46% increase by 2050 [3]. The growing population in this region will also continue to face environmental threats and challenges, including water scarcity, soil degradation, desertification, and low agricultural production that threaten food security for the present and future generations.

Thus, it is essential to ensure the proper availability and accessibility to high quality, nutritious and sustainable diets to warrant food and nutrition security for the growing population.

According to the Food and Agriculture Organization (FAO) of the United Nations, sustainable diets are defined as "protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy while optimizing natural and human resources" [4]. Typically, these sustainable diets are also high in plant-based foods and low in processed and animal-based foods. Plant-based foods have a variety of reported health benefits, particularly reduction in the risks related to cardiovascular diseases (CVD) and mortality. Diets rich in plant-based foods have been shown to reduce risk of death from CVD by up to 40%, risk of coronary heart disease by up to 40%, and risk of hypertension by up to 34% [5–9]. In relation to environmental factors, research has shown that plant-based diets are associated with decreased GHG emissions, vegan diets reporting the most extensive reduction (70% decrease) [10]. Sustainable healthy diets rich in plant-based foods and low in excess energy, red and/or processed meat, and refined sugar were also found to be more affordable [11]. In 2019, the EAT-Lancet Commission proposed the global planetary health diet, which aims to promote a healthy diet for humans while ensuring that we are producing food within our planetary boundaries. The Commission recommended the adoption of an eating pattern that mostly focuses on vegetables, fruits, legumes and nuts, whole grains, and unsaturated oils, and includes only low amounts of seafood and poultry, while shifting away from red meat, processed meat, added sugar, refined grains, and starchy vegetables [12]. Nevertheless, the adoption of such a sustainable and healthy diet remains a challenge for most of the world's population, particularly those residing in regions with high political instabilities and protracted conflicts, such as the MENA region.

Lebanon is a small middle-income country in the MENA region facing serious economic, environmental, and health threats that are jeopardizing its food and nutrition security. With a population of just over 6 million people and with the highest per capita concentration of refugees worldwide [13], Lebanon has undergone decades of political unrest, wars, weak fiscal policies, pervasive corruption, and improper management of resources that have crippled the country's economic growth and stability. Over the past two years, the country has endured multiple crises, including a new wave of national protests and civil unrest since October 2019 [14], a political gridlock, a dramatic economic collapse along with the COVID-19 global pandemic, and lastly, the tragic explosion in Beirut's port in 2020 that pushed the country beyond its limits. Together, these unfortunate circumstances and events led to an unprecedented situation threatening the food security and livelihoods of an entire population.

Prior to the pandemic, Lebanon was undergoing an unfavorable nutrition transition, shifting the dietary intake of children and adults away from the traditional Mediterranean diet toward the consumption of a more Western-like diet rich in energy-dense and highly processed foods. According to Naja et al. [15], significant changes were noted in the diet of Lebanese adolescents between 1997 and 2009 that are characterized by high intakes of meat, poultry, salty snacks, added fats and oils, whereas the consumption of milk and fruits significantly decreased among this age population during that time period. This dietary shift along with the increase in sedentary behaviors and lifestyles were associated with an increase in excessive weight gain and diet-related non-communicable diseases (NCDs), including diabetes, hypertension and cardiovascular diseases [16]. Children represent a vulnerable population that can be greatly affected by these dietary shifts and lifestyle transitions, affecting their health on the short- and long-term [17]. Based on data collected in 2012, the prevalence of preschoolers who were classified as either overweight or obese (9.1%) in Lebanon [18] exceeded the global prevalence estimate of preschool overweight and obesity (6.7%) [19]. The global prevalence of pediatric overweight and obesity has also been on the rise among school-aged children, reaching 18% in 2016 [20]. Studies have also shown that Lebanese children are consuming suboptimal diets that are high in fat, saturated fat, and sugar, yet low in key micronutrients, including iron, calcium, zinc, folic acid, vitamin A, and vitamin D [21]. Since dietary habits acquired during early life have been shown to influence health later in life, particularly obesity, cardiovascular disease and diabetes [22,23], a balanced healthy diet early in life is essential for optimal health throughout adolescence and into adulthood.

The dietary shifts observed among Lebanese children and adolescents are also threatening the environmental sustainability of Lebanese diets. These shifts in food consumption were associated with significant increases in greenhouse gas (GHG) emissions, water and energy footprints [15]. Thus, diet solutions that are healthy, satisfy nutrient needs, and consider economic and environmental factors are much needed. In fact, there is a growing scientific literature from high income countries on diet optimization, a mathematical approach to derive optimal diets given certain functions and constraints, particularly those that are environment related [24,25]. One of these diet optimization techniques include the use of the Optimeal Software [26], which was previously used to integrate wider issues of sustainability. Such issues include identifying diets that do not exceed global GHG emission targets, showing the environmental performance of different foods, and recognizing affordable dietary options that alleviate environmental impact without posing nutritional challenges [27–31]. However, there remains a gap in the scientific literature on the use of diet optimization techniques in low to middle income countries, such as Lebanon, that are undergoing heightened environmental and economic constraints along with other pressing nutrition and health-related challenges.

Therefore, the aim of this study is to propose healthy and sustainable dietary recommendations that would provide Lebanese children with essential nutrients needed for their growth and development while balancing the trade-offs among the economic, health, and environmental dimensions of sustainability.

2. Materials and Methods

In the present study, a diet optimization approach for children (4–18 years of age) was adopted, using Optimeal, an online software used to produce an optimized dietary pattern that takes into consideration nutritional, dietary, environmental, and cost constraints. Constraints were set for food items within food groups based on recommendations by the EAT-Lancet Commission, the American Heart Association (AHA), and the Mediterranean Diet (MD) [12,32,33]. Data were stratified to resemble the food intake pattern in Lebanon as closely as possible, using existing data and expert opinion. Nutrient constraints were set, according to the standard age-based dietary reference intakes (DRIs), namely the estimated average requirement (EAR) and the tolerable upper limit intake (UL) [34]. The minimum and maximum constraints for vitamins and minerals were age specific and took into consideration gender differences where applicable. Moreover, environmental and cost constraints were considered in accordance with the values of EFPs (namely, water use, energy use, and greenhouse gas (GHG) emissions) and the current cost of the national diet. The optimized dietary pattern was the pattern most similar to the national diet that also satisfies all the identified nutritional, dietary, environmental, and cost constraints. Further details for the nutrition, environmental and cost constraints are presented in Sections 2.2 and 2.3 in the present study.

2.1. Study Population

Data for the nationally consumed diets (reference diet) for children in the present study were based on the Lebanese Food and Nutrition Security Survey (L-FANUS), a cross sectional survey of Lebanese households with children aged 4–18 years conducted between December 2014 and November 2015. Following a stratified cluster sampling strategy, clusters were drawn from the twenty-six districts in the six Lebanese governorates. Based on a probability-proportional-to-size approach, a higher number of households was drawn from districts with higher population density, using data from the Lebanese Central Administration of Statistics. For a household to be eligible, it had to include a mother and one child between 4 years and 18 years of age. Both the mother and the child had to be of Lebanese nationality and had to be healthy (not suffering from any chronic disease or taking any medications that may interfere with body composition or overall nutritional status) at the time of the interview. Data were gathered through face-to-face interviews with the mothers if the child was aged less than 10 years, and with the child directly in the presence of their mother if aged 10 years and above. Dietary intake was assessed with the help of trained dietitians using single 24 h dietary recalls. Details about the data collection, anthropometric assessment, and dietary intake assessment can be found elsewhere [35].

The original survey included 1209 children. Complete dietary data were available for 1154 children who were included in the final analysis within the present study. The sample was further divided into three age groups, and in accordance with the AHA dietary recommendations for children and adolescents: [(4 to 8 years (n = 392), 9 to 13 years (n = 473), and 14 to 18 years (n = 289)] [36].

2.2. Dietary Data and Food Groups

Dietary data from the national survey were revised by the research team (nutrition experts) to put together the food groups in the optimized models in alignment with the EAT-Lancet Commission, AHA, and MD recommendations. An overview of the food groups and the food items within each food group is described in Supplementary Table S1. For the current study, composite and mixed dishes were dissected into individual food items, which were then regrouped into different food groups. Few items were not included in the food groups considered part of the diet optimization process, and these food items included condiments, herbs, spices, water, and diet sodas. Please see Section 2.3.5. for further details regarding the minimum and maximum constraints used in the models.

2.3. Optimization Calculations

2.3.1. Optimization Model

The calculations that resulted in the optimal diets were performed using the optimization model in Optimeal [26]. Optimeal is a software that uses optimization to solve dietary questions that involve nutritional, economical, and sustainability parameters. It was used to compute diets similar to the national diet while satisfying a set of dietary, nutritional, environmental and cost requirements. This method of optimization was previously used for deriving an optimized sustainable diet for Lebanese adults [37]. It was also adopted by different authors in multiple diet comparison/optimization studies included in our literature [24,27–31].

2.3.2. Health/Nutrition Constraints

The basic principle is that the optimized diet includes dietary patterns that closely resemble the current nationally consumed diet and meets international dietary recommendations for energy and nutrients. Energy constraints were based on nationally consumed calories to resemble the current national diet, while shifting away from food groups poor in nutrients and more toward nutrient-dense foods. In order to prevent under or over-consumption, caloric constraints were set based on dietary recommendations as well as expert judgement. Since males have higher caloric needs than females and to satisfy the caloric needs of both, the minimum calories were set to match the caloric recommendations of inactive males by the AHA according to age, while the caloric maximums were set similar to the nationally consumed caloric intake of each age group. An exception was the 14–18 age group, where the minimum constraint was set as the average national caloric intake, and the maximum constraint was set as the AHA recommendation, due to the national consumption being lower than the recommendation for this age group. These constraints were listed in Supplementary Table S2.

2.3.3. Macronutrient Constraints

Constraints for carbohydrate, fat, and protein were set according to the acceptable macronutrient distribution range (AMDR) established by the Institute of Medicine (IOM) for the specified age groups [38]. The minimum macronutrient constraint was based on the lower limit of the AMDR along with the minimum caloric constraint, while the maximum macronutrient constraint was based on the higher limit of the AMDR and the maximum caloric constraint. Constraints were set to not exceed 25 g and 8% for added sugar and saturated fat, respectively, as per the recommendations of the AHA and the World Health Organization (WHO) [32,39]. Macronutrient constraints were presented in Supplementary Table S2.

2.3.4. Micronutrient Constraints

Micronutrient minimums and maximums were placed according to the standard age-based dietary reference intakes (DRI) established by the Institute of Medicine at the National Academies of Sciences, Engineering, and Medicine (NASEM) [34]. Minimums were set as the estimated average requirement (EAR), which is the intake level for a nutrient that meets the need of 50% of the population, akin to similar studies [24,37]. For age groups 9–13 years and 14–18 years, the male EAR values were used for minimum constraints, as males tend to have slightly higher nutrients needs than females. An exception to this was the minimum constraint for iron in the 14–18 age group, where the female EAR was used as a minimum constraint since females of that age group have higher iron needs than males. Maximums, on the other hand, were set as the tolerable upper limit intake (UL), which is the highest possible nutrient intake that is likely to pose no adverse risk on the general population [40]. There were no maximum constraints set for vitamins B1, B2, and B12 for any of the age groups, given the lack of UL cutoffs for these vitamins as per the latest NASEM guidelines [34]. All micronutrient constraints are listed in Supplementary Table S2.

2.3.5. Food Groups and Food Item Constraints

Constraints for the daily intake of food groups and food items were based on the following: (1) recommendations from the EAT-Lancet Commission, the AHA, and the MD, and (2) the percent distribution of the nationally consumed food items within their designated food groups (as per the reference diet). For example, bread constitutes 52% of the cereals and grains food group consumption for 4–8-year-old children as seen in Table 1 (from reference diet). Thus, the minimum and maximum constraints for bread in the optimized models were set at 52% of the cereals and grains food group recommendations of the EAT-Lancet Commission. As for the minimum constraint for the daily intake of fish, it was set to match that of the national diet, and the maximum constraint was based on the minimum recommendation of the EAT-Lancet Commission. This was done to minimize the shift from the national diet, which is much lower in fish intake and due to the high cost of fish, particularly during the economic crisis that the country has been witnessing over the past two years [41]. The maximum constraint of fresh fruit juices was also set to match the national daily intake to prevent an increase in the food group. In addition, the vegetable group was only subjected to a minimum constraint to encourage children to eat more of these nutrient-dense foods. Since the consumption of processed meat and salty snacks is recommended to be substantially restricted, the maximum constraint of such foods was set as "0". The constraints of the sugar/jam/honey, sweets, and sugar-sweetened beverages (SSB) groups were based on the percent distribution of added sugar according to the AHA recommendation [32]. First, the percentage of added sugar that each of these food groups contributed was calculated. Then, the same percentage was used to calculate the added sugar that each food group would contribute if the total was the 25 g that is recommended by AHA. Finally, the ratio of added sugar to whole weight was used to calculate the maximum permissible weight of sugar/jam/honey, sweets, and SSB groups, which was finally used as the maximum constraint. All the constraints for food groups and food items for age groups 4–8 years, 9–13 years, and 14–18 years are depicted in Tables 1–3, respectively.

Table 1. Food group/item minimum and maximum constraints for children aged 4–8 years.

Food Products	Reference Diet (National Consumption) (g)	Percent Distribution from Food Group (%)	Based on Recommendations	
			Minimum (g/Day)	Maximum (g/Day)
Cereals and Grains	162.13	-	149.47 [E]	241.60 [E]
Bread	84.41	52.07	77.82	125.79
Cooked Bulgur	4.59	2.83	4.23	6.84
Cooked Rice	43.69	26.95	40.28	65.11
Ready to Eat Breakfast Cereal	2.43	1.50	2.24	3.62
Cooked Pasta	27.00	16.65	24.89	40.23
Fruits	141.10	-	-	-
Fresh Fruits	114.19	80.93	104.28 [E]	156.41 [E]
Dried Fruits	0.59	0.42	0.54 [E]	0.81 [E]
Fresh Fruit Juices	26.32	18.65	-	26.32 *
Vegetables	126.15	-	-	-
Dark and Green Vegetables	16.70	13.23	64.43 [E]	-
Red and Yellow Vegetables	49.30	39.08	64.43 [E]	-
Other Vegetables	60.16	47.69	64.43 [E]	-
Starchy Vegetables	40.44	-	32.21 [E]	64.43 [E]
Potatoes	37.78	93.42	30.09	60.19
Corn	2.66	6.58	2.12	4.24
Dairy Products	122.71	-	161.07 [E]	322.14 [E]
Milk	39.20	31.95	51.46	102.91
Yogurt	40.68	33.15	53.40	106.80
Cheese	27.49	22.41	36.09	72.18
Labneh/Strained yogurt	15.33	12.49	20.12	40.25
Meat	18.73	-	9.02 [E]	18.04 [E]
Poultry	24.11	-	18.68 [E]	37.37 [E]
Fish	4.31	-	4.31 *	18.04 [E]
Eggs	8.55	-	8.38 [E]	16.11 [E]
Legumes	16.01	-	-	64.43 ‡
Nuts and Seeds	6.07	-	6.07 *	48.32 [E]
Saturated Oils	1.49	-	-	7.60 [E]
Vegetable/Unsaturated Oils	21.40	-	21.4 *	51.54 [E]
Processed Meat	8.73	-	-	0
Salty Snacks §	24.44	-	-	0
Sugar/Jam/Honey	3.30	-	-	1.79 ⁂
Sweets	81.07	-	-	43.92 ⁂
SSB #	225.66	-	-	122.25 ⁂

[E] EAT-Lancet Commission Recommendations [12]. * National Consumption. ‡ Mediterranean Diet Recommendations [33]. ⁂ Based on % distribution from AHA added sugar recommendation [32]. § Salty snacks, such as salty crackers, potato chips, and pretzels. # Sugar-sweetened beverages (SSB), including bottled fruit juices, canned fruit juices, lemonade, fruits canned in heavy syrup, and sodas.

Table 2. Food group/item minimum and maximum constraints for children aged 9–13 years.

Food Products	Reference Diet (National Consumption) (g)	Percent Distribution from Food Group (%)	Based on Recommendations	
			Minimum (g/Day)	Maximum (g/Day)
Cereals and Grains	181.49	-	184.82 [E]	298.75 [E]
Bread	103.27	56.90	105.16	169.99
Cooked Bulgur	5.98	3.29	6.09	9.84
Cooked Rice	50.42	27.78	51.34	82.99
Ready to Eat Breakfast Cereal	1.84	1.01	1.88	3.03
Cooked Pasta	19.99	11.01	20.35	32.90
Fruits	153.72	-	-	-
Fresh Fruits	114.62	74.56	118.80 [E]	178.21 [E]
Dried Fruits	0.13	0.09	0.14 [E]	0.21 [E]
Fresh Fruit Juices	39	25.35		38.96 *
Vegetables	137.19	-	-	-
Dark and Green Vegetables	21.84	15.92	79.67 [E]	-
Red and Yellow Vegetables	55.18	40.22	79.67 [E]	-
Other Vegetables	60.18	43.87	79.67 [E]	-
Starchy Vegetables	57.38	-	39.83 [E]	79.67 [E]
Potatoes	53.11	92.55	36.87	73.73
Corn	4.27	7.45	2.97	5.93
Dairy Products	114.35	-	199.16 [E]	398.33 [E]
Milk	32.10	28.08	55.92	111.83
Yogurt	33.47	29.27	58.30	116.60
Cheese	33.98	29.72	59.18	118.37
Labneh/Strained yogurt	14.79	12.94	25.76	51.53
Meat	30.78	-	11.15 [E]	22.31 [E]
Poultry	40.56	-	23.10 [E]	46.21 [E]
Fish	4.83	-	4.83 *	22.31 [E]
Eggs	9.39	-	10.36 [E]	19.92 [E]
Legumes	18.93	-	-	79.67 ‡
Nuts and Seeds	9.42	-	9.42 *	59.75 [E]
Saturated Oils	2.43	-	-	9.40 [E]
Vegetable/Unsaturated Oils	31.05	-	31.05 *	63.73 [E]
Processed Meat	5.65	-	-	0
Salty Snacks §	36.12	-	-	0
Sugar/Jam/Honey	5.52	-	-	2.52 ⁂
Sweets	82.93	-	-	37.79 ⁂
SSB #	327.29	-	-	149.16 ⁂

[E] EAT-Lancet Commission Recommendations [12]. * National Consumption. ‡ Mediterranean Diet Recommendations [33]. ⁂ Based on % distribution from AHA added sugar recommendation [32]. § Salty snacks, such as salty crackers, potato chips, and pretzels. # Sugar-sweetened beverages (SSB), including bottled fruit juices, canned fruit juices, lemonade, fruits canned in heavy syrup, and sodas.

Table 3. Food group/item minimum and maximum constraints for children aged 14–18 years.

Food Products	Reference Diet (National Consumption) (g)	Percent Distribution from Food Group (%)	Based on Recommendations	
			Minimum (g/Day)	Maximum (g/Day)
Cereals and Grains	186.33	-	179.44 [E]	290.04 [E]
Bread	96.77	51.94	93.20	150.64
Cooked Bulgur	4.02	2.16	3.87	6.26
Cooked Rice	64.05	34.38	61.68	99.70
Ready to Eat Breakfast Cereal	1.55	0.83	1.49	2.41
Cooked Pasta	19.93	10.70	19.20	31.03
Fruits	145.52	-	-	-
Fresh Fruits	114.68	78.81	121.91 [E]	182.87 [E]
Dried Fruits	0.08	0.06	0.09 [E]	0.13 [E]
Fresh Fruit Juices	30.75	21.13		30.75 *
Vegetables	175.78	-	-	-
Dark and Green Vegetables	34.08	19.39	77.34 [E]	-
Red and Yellow Vegetables	67.22	38.24	77.34 [E]	-
Other Vegetables	74.49	42.38	77.34 [E]	-
Starchy Vegetables	62.28	-	38.67 [E]	77.34 [E]
Potatoes	60.27	96.77	37.42	74.84
Corn	2.01	3.23	1.25	2.50
Dairy Products	89.77	-	193.36 [E]	386.72 [E]
Milk	16.21	18.06	34.92	69.85
Yogurt	25.36	28.25	54.63	109.25
Cheese	33.38	37.18	71.90	143.79
Labneh/Strained yogurt	14.82	16.50	31.91	63.82
Meat	38.36	-	10.83 [E]	21.66 [E]
Poultry	35.89	-	22.43 [E]	44.86 [E]
Fish	12.06	-	12.06 *	21.66 [E]
Eggs	11.06	-	10.05 [E]	19.34 [E]
Legumes	19.07	-	-	77.34 ‡
Nuts and Seeds	11.46	-	11.46 *	58.01 [E]
Saturated Oils	1.60	-	-	9.13 [E]
Vegetable/Unsaturated Oils	30.68	-	30.68 *	61.87 [E]
Processed Meat	5.56	-	-	0
Salty Snacks §	29.28	-	-	0
Sugar/Jam/Honey	4.54	-	-	2.13 ⁑
Sweets	64.20	-	-	30.12 ⁑
SSB #	367.43	-	-	172.36 ⁑

E EAT-Lancet Commission Recommendations [12]. * National Consumption. ‡ Mediterranean Diet Recommendations [33]. ⁑ Based on % distribution from AHA added sugar recommendation [32]. § Salty snacks, such as salty crackers, potato chips, and pretzels. # Sugar-sweetened beverages (SSB), including bottled fruit juices, canned fruit juices, lemonade, fruits canned in heavy syrup, and sodas.

2.3.6. Environmental Footprint and Cost Constraints

To ensure that the derived diets are sustainable environmentally and economically, constraints for environmental footprints (EFPs), namely water use, energy use, and greenhouse gases emission, and cost were set to match those of the national diets.

For the environmental constraints, existing life cycle assessments (LCA), which are methods that assess the impact of a product or a service on the environment, were used to calculate environmental footprints per 1 kg of each food item in each age group's national diet. It is important to point out that LCAs previously conducted in Mediterranean or neighboring countries that have a comparable climate to Lebanon were prioritized [42]. A detailed description of the LCAs used to derive the EFPs used in the present study are presented elsewhere [43].

The cost of food groups was calculated by averaging the costs of 1 g of the different food items that the group is composed of. For instance, the cost of legumes was calculated by summing the average cost of 1 g of lentils, fava beans, kidney beans, and chickpeas, all of which are consumed by the Lebanese population. The applied cost of each food item was drawn from the market cost in October 2020, as presented by the Lebanese Ministry of Economy and Trade (MoET). The exceptions were fish, salty snacks, sweets, and SSB, due to their absence from the ministry's report. For these food items, data were used from a 2019 survey conducted in Beirut about the prices of specific items sold in the Lebanese markets to calculate the cost. In this survey, a total of 12 types of food retail outlets within Beirut were contacted. These included privately owned supermarkets, publicly owned cooperatives, corner stores, greengrocers, butchers, fish markets, dairy stores, bakeries, traditional bakeries selling a limited range of ready-to-eat bread-based products, roasteries, Arabic sweets shops, and restaurants. To be more representative of usual price listings, the prices recorded were for only non-sale items. The data regarding costs of fish, salty snacks, sweets, and SSB in 2019 that were extracted from this survey were recalculated to match the dollar rate of LBP 3900 to mimic the prices that these foods would cost in October 2020 [44]. Finally, the cost of the usual mean intake was calculated based on the national food group consumption of each age group. Supplementary Table S3 contains all the environmental and cost constraints.

3. Results

For all the different age groups of children considered in the present study, optimization models provided dietary patterns that met all the health, environmental and cost constraints placed. Three different optimized diets were derived that meet the nutritional needs of children according to their age group (calories, macro- and micronutrients) and simultaneously fall within the minimums and the maximums that were set for EFPs (water usage, energy usage, GHG emission) and cost. Overall, extensive variations between the derived optimized diets and the national diet across the three age groups were noted for several food groups (Table 4). Results of the optimized diets highlight the need for a significant increase in the consumption of vegetables (+201%), especially dark green vegetables (+678%), legumes (+218%), and certain dairy products, such as cheese (+129) and labneh/strained yoghurt (+247%), compared to the national diets of children in all three age groups (4–8, 9–13, and 14–18 years). On the other hand, the models suggest the need for reductions in consumption of processed meats, salty snacks, sweets, and sugar-sweetened beverages (average reduction: −90%) compared to the national diets of Lebanese children (three age groups). As shown in Table 5, these changes will result in improvements in the nutrient intake of children in all considered age groups, including vitamins A (+183%), vitamin C (+114), dietary folate (+99%), and calcium (+99%). Associated cost and EFPs will be also decreased across all age groups with the optimized diets (Table 5).

Table 4. Change (in percentage (%) and in grams (g)) of food groups consumed within the optimized diet as compared to the national diet of Lebanese children, on average and by age groups.

Food Groups	4–8 Years	9–13 Years	14–18 Years	Average of All Age Groups
		±% (g)		
Cereals and Grains	+26 (42.7)	+36 (66.2)	+40 (75.0)	+34 (61.3)
Bread	+23 (19.6)	+30 (30.7)	+26 (25.2)	+26 (25.2)
Cooked Bulgur	+49 (<15)	+65 (<15)	+56 (<15)	+57 (<15)
Cooked Rice	+23 (<15)	+35 (17.9)	+56 (35.7)	+38 (21.2)
Ready to Eat Breakfast Cereals	+49 (<15)	+65 (<15)	+55 (<15)	+56 (<15)
Cooked Pasta	+35 (<15)	+62 (<15)	+56 (<15)	+51 (<15)
Fruits	+6 (<15)	+10 (15.5)	+37 (53.8)	+18 (25.8)
Fresh Fruits	+6 (<15)	+14 (15.4)	+49 (56.3)	+23 (26.5)
Dried Fruits	+37 (<15)	+62 (<15)	+63 (<15)	+54 (<15)
Fresh Fruit Juices	N.C. (0)	N.C. (0)	−8 (<15)	−3 (<15)
Vegetables	+72 (91.0)	+169 (232.1)	+361 (635.2)	+201 (319.4)
Dark and Green Vegetables	+380 (63.5)	+768 (168.2)	+886 (301.9)	+678 (177.9)
Red and Yellow Vegetables	+31 (<15)	+44 (24.5)	+134 (90.8)	+70 (43.5)
Other Vegetables $^{\beta}$	+21 (<15)	+66 (39.4)	+325 (242.5)	+137 (98.1)
Starchy Vegetables	−20 (<15)	−31 (17.5)	−38 (23.6)	−30 (16.4)
Potatoes	−20 (<15)	−31 (16.2)	−38 (22.9)	−30 (15.6)
Corn	−20 (<15)	−30 (<15)	−38 (<15)	−29 (<15)
Dairy Products	+70 (85.6)	+117 (134.1)	+151 (135.4)	+113 (118.4)
Milk	+31 (<15)	+74 (23.8)	+115 (18.7)	+73 (18.3)
Yogurt	+31 (<15)	+74 (24.8)	+115 (29.2)	+73 (22.3)
Cheese	+129 (35.6)	+143 (48.7)	+115 (38.5)	+129 (41.0)
Labneh/Strained yogurt	+163 (25.0)	+248 (36.7)	+331 (49.0)	+247 (36.9)
Meat	−52 (<15)	−64 (19.6)	−64 (24.5)	−60 (17.9)
Poultry	−23 (<15)	−43 (17.5)	−38 (<15)	−35 (<15)
Fish	N.C. (0)	N.C. (0)	+10 (<15)	+3 (<15)
Eggs	−2 (<15)	+10 (<15)	−9 (<15)	0 (<15)
Legumes	+121 (+19.3)	+228 (43.2)	+306 (58.2)	+218 (40.2)
Nuts and Seeds	N.C. (0)	N.C. (0)	N.C. (0)	N.C. (0)
Saturated Oils	−100 (<15)	−100 (<15)	−100 (<15)	−100 (<15)
Vegetable/Unsaturated Oils	N.C. (0)	N.C. (0)	N.C. (0)	N.C. (0)
Processed Meat	−100 (<15)	−100 (<15)	−100 (<15)	−100 (<15)
Salty Snacks §	−100 (24.4)	−100 (36.1)	−100 (29.3)	−100 (29.9)
Sugar/Jam/Honey	−46 (<15)	−54 (<15)	−53 (<15)	−51 (<15)
Sweets	−100 (81.1)	−100 (82.9)	−100 (64.2)	−100 (76.1)
SSB #	−46 (103.7)	−54 (178.3)	−77 (283.0)	−59 (188.3)

§ Salty snacks such as salty crackers, potato chips, and pretzels. # Sugar-sweetened beverages (SSB), including bottled fruit juices, canned fruit juices, lemonade, fruits canned in heavy syrup, and sodas. $^{\beta}$ Other vegetables, including zucchini, eggplant, cabbage, green beans, cucumber, radish, red onion, and garlic. N.C.: no change.

Table 5. Percent change (±%) in the environmental footprints (EFPs), cost, macro- and micronutrients within the optimized diet as compared to the national diet of Lebanese children on average and by age group.

	4–8 Years	**9–13 Years**	**14–18 Years**	**Average of All Age Groups**
EFPs and Cost				
Water	−21	−19	−19	−20
Energy	−19	−15	-	−11
GHG	−27	−23	−16	−22
Cost/day	−29	−22	−9	−20
Calories	−13	−10	-	−8
Macronutrients				
Carbohydrates	−16	−11	+5	−7
Added Sugar	−70	−71	−78	−73
Protein	+11	+17	+30	+19
Fat	−17	−16	−12	−15
Saturated fat	−28	−25	−21	−25
Micronutrients				
Vitamin A	+66	+152	+332	+183
Vitamin B1	+11	+23	+55	+30
Vitamin B2	+13	+32	+66	+37
Vitamin B3	−11	−14	−4	−10
Vitamin B12	−19	−33	−31	−28
Vitamin C	+35	+114	+193	+114
Calcium	+56	+101	+140	+99
Iron	+11	+63	+109	+61
Zinc	−13	−4	+9	−3
Dietary Folate	+31	+85	+182	+99

3.1. Optimization Calculations for Children Aged 4–8 Years

The results of the optimized diet for children 4–8 years of age are displayed in Table 4. This final optimized diet met all the nutritional, dietary, environmental, and cost constraints that were placed. Large variations between the national diet and the optimized were observed for some food groups. For example, there was a high percent change from the national consumption of dark and green vegetables (+380%), labneh/strained yogurt (+163%), and legumes (+121%). Other changes noted in the optimization model were for foods that should be decreased in consumption by 100 percent, compared to the national diet of children in this age group, such as changes in the intake of processed meat, saturated oils, salty snacks, and sweets. Other smaller changes were also noted for food groups/items, such as milk (+31%) and sugar/jam/honey (−46%), compared to the national diet.

All these changes were mainly to satisfy the dietary constraints, which can lead to a noticeable increase in vitamin A (+66%) and calcium (+56%), and a decrease in added sugars (−70%), as shown in Table 5. In addition, calories, carbohydrates, and fat decreased by 13%, 16% and 17%, respectively, while protein increased by 11%. All mentioned changes were accompanied by a decrease in EFPs, including water use (−21%), energy use (−19%), and GHG emissions (−27%). The cost per day per person for the optimized diet was calculated to be LBP 10,800 (USD 2.77), which displayed a 29% decrease from the national diet.

3.2. Optimization Calculations for Children Aged 9–13 Years

According to the results of the optimization model for 9–13-year-old children, the most extensive variations between the optimized diet and the national diet were seen in dark and green vegetables (+768%), Labneh/strained yogurt (+248%), cheese (+143%), and legumes (+228%). Furthermore, the optimized model showed that consumption of saturated oils, processed meat, salty snacks, and sweets decreased by 100%. Other variations were less considerable. Fresh fruits and eggs consumption increased by 14% and 10%, respectively, while fish and nuts and seeds consumption remained unchanged.

The most percent changes seen in micronutrients between the national diet and the optimized diet for children in this age group were noted with vitamin A (+152%), vitamin C (+114%), calcium (+101%), and dietary folate (85%) with slightly smaller changes accompanying iron (+63%). The optimized diet also displayed a decrease in calories (−10%), added sugar (−71%), and saturated fat (−25%), and an increase in protein (+17%) when compared to the national diet. The cost of the optimized diet was calculated to be LBP 14,100 (USD 3.62) per day per person, which was marked as a 22% decrease from the cost of the national diet. Additionally, the optimized diet presented reduced water use, energy use, and GHG emissions by 19%, 15%, and 23%, respectively. All results of the optimized model for macro- and micronutrients, EFPs, and cost can be found in Table 5.

3.3. Optimization Calculations for Children Aged 14–18 Years

Table 4 displays the results of the optimized diet for children aged 14–18 years satisfying all constraints. Results of the optimized diet show a need to greatly increase the consumption of vegetables (+361%), especially dark and green vegetables (+886%), and legumes (+306%), compared to the national diet of 14–18-year-old children. Other remarkable changes were noted for all dairy products (+151%), including milk (+115%), yogurt (+115%), cheese (+115%), and labneh/strained yogurt (+331%). The optimized diet presented an increase in cereals and grains by 40%, and an increase in fruits by 37%, which was marked as the highest change in fruits when compared to changes in the younger age groups (4–8 and 9–13-year-old children). Furthermore, a decrease was seen in processed meat (−100%), salty snacks (−100%), sugar/jam/honey (−53%), sweets (−100%), and SSB (−77%).

These changes led to a decrease in the use of water (−19%) and emission of GHG (−16%), while there was no change in the use of energy. Furthermore, this optimized model increased the diet's composition of protein (+30%) and carbohydrates (+5%), while decreasing the fat composition by 12% and matching the calorie count of the national diet (1930 kcal/day). A notable decrease was seen in added sugars (−78%) compared to the national diet for 14–18year-old children. The optimized diet also satisfied all the micronutrient constraints set to match the needs of Lebanese children for that age group by significantly increasing the intakes of vitamin A (+332%), vitamin C (193%), dietary folate (+182%), calcium (+140%), and iron (109%). As for cost, the optimized diet was lower by 9% compared to the cost of the national diet. All changes and variations between the national diet and the optimized diet regarding macro- and micronutrients, EFPs, and cost can be found in Table 5.

4. Discussion

The present study combined optimization modeling and the most recently available national dietary data for children in Lebanon to propose dietary recommendations that consider trade-offs among nutritional/health-related, environmental, and economic parameters of sustainability. Three different optimized diets were derived that meet the nutritional needs of children (calories, macro- and micronutrients), according to their age groups (4–8, 9–13, and 14–18 years), and, simultaneously, fall within the minimum and the maximum constraints that were set for EFPs (water usage, energy usage, and GHG emissions) and cost.

Overall, considerable variations were noted in the present study between the national diets consumed, on average, across the three age groups and the optimized diets. Our results highlight the need for an increase in vegetable intake by 201%, dairy intake by 113%, and legume intake by 218%. Our models also suggested the need for reductions in the consumption of less nutritious foods, such as saturated oils, processed meats, sugar, salty snacks, sweets, and sugar-sweetened beverages. These results corroborate the findings from previous studies following diet optimization approaches, where an increase in plant-based foods and a decrease in sugars and fatty foods were recommended [29,31,37]. Similarly, the EAT-Lancet Commission requires substantial dietary shifts, including a greater than

100% increase in healthy foods intake, including vegetables and legumes, and more than a 50% reduction in the consumption of foods such as sugar and red meat in order to transform to healthy diets by 2050 [12]. Previous studies highlight the erosion of the MD among children and adolescents in Lebanon, a diet that is characterized by the high consumption of fruits, vegetables, legumes and nuts [16,37,45]. According to Naja et al. [37], the adherence of Lebanese children to the MD declined significantly between 1997 and 2015, and the temporal trends were projected to worsen over time (with less than a quarter of the adolescent population expected to remain adherent to this diet by 2030). The shift away from the MD, which is known for its protective health effects and that is rich in vitamins and minerals [46], toward more energy-dense diets can have serious repercussions on the health and nutritional status of Lebanese children. Such dietary shifts can increase their risk for dietary inadequacies, micronutrient deficiencies, and excessive weight gain [19,21].

The optimized diets derived in the present study that focus on increasing the intake of children from plant-based foods and reducing the intake of energy-dense foods were also shown to decrease EFPs, including water use, energy use, and GHG emissions, by an average of 20%, 11%, and 22%, respectively, when compared to the national diet. This is important, as the EAT-Lancet Commission predicts that by following the current dietary trends, humans could lessen the stability of the earth systems, due to the effects of food production on EFPs, such as water and land use, pollution, and GHG emissions [12]. Recent research also noted that sustainable diets were associated with approximately 25% less GHG emissions as well as reductions in land and nitrogen use. More significant shifts to vegan, vegetarian, ovolactovegetarian, flexitarian, or pescatarian diets led to further reductions in GHG emissions [10,47]. Although previous studies showed that some sustainable diets can have a higher water requirement for their production than current consumed diets [10], our study reported a decrease in water use by 21%, 19%, and 19% for the optimized diets of 4–8, 9–13, and 14–18 age groups, respectively. This difference in outcomes could be attributed to the different socioeconomic populations and income projections that were considered in such studies, which can change the absolute number of foods demanded and, thus, lead to different water requirements. Overall, studies indicated that a diet higher in plant-based foods, such as vegetables, legumes and whole grains, and lower in animal-based foods (especially red meat) can be associated with health-related benefits and with a reduced impact on the environment [48].

Compared to other age groups, children aged 14–18 years had the highest variations between the food groups in the national diet and the optimized diet. Regarding vegetable consumption, the 14–18 age group had to increase their intake by 361%, while the 4–8 and 9–13 age groups had to increase their intake by 72% and 169%, respectively. The same trend was observed with the increase in the consumption of legumes and dairy and decrease in the consumption of starchy vegetables and SSBs, in which the 14–18 age group had a higher variation between the national diet and optimized diet than the other two food groups. This is understandable, as teenagers tend to spend more time outside of the house, where choices including unhealthy diets are highly prevalent [49].

Our optimized diet decreased cost by 29%, 22%, and 9% (average of 20%) for the three age groups (4–8, 9–13, and 14–18-year-old children), respectively. This is in line with other studies that found that sustainable diets are more affordable (cost ~20% less) than their respective national diets [11,50]. Even though some studies have also shown that healthier foods are more expensive than their non-healthy counterparts with the largest share being the cost of vegetables and fruits followed by legumes [51,52], local data regarding the price of plant-based foods from countries around the world are still limited. Moreover, the cost of highly perishable foods, such as fruits and vegetables, may vary greatly depending on seasonality, supply and demand, local production, and distribution efficiency [53,54]. In the present study, an increase in vegetables and fruits was seen in the optimized diet, yet the decrease in cost within the models can be attributed to the lower cost of locally produced fruits and vegetables, compared to other food items, such as red meat, chicken and fish, especially in light of the recent financial crisis in Lebanon [41,55]. It is worth noting that with the devaluation of the Lebanese currency over the past two years (losing over 80% of its value), restricted access to foreign currencies, inflation in prices of food and non-food items, the people's purchasing power and ability to access basic goods, such as food, has also been dramatically restricted [56]. The Lebanese Ministry of Social Affairs estimated that the COVID-19 pandemic's effects on top of the economic crisis have led to an increase of 50 percent in unemployment rates, pushing families further into poverty and vulnerability [57]. A recent report by the United Nationals Children's Fund (UNICEF) further warned that children in Lebanon are bearing the brunt for one of the world's worst economic crises, with over 30 percent of children going to bed hungry and skipping meals, affecting their health, education and future [58]. The prevalence of food insecurity in Lebanon is expected to further increase if serious and immediate measures are not taken to halt the spiraling economic crisis and its adverse impacts on the most vulnerable households and communities [59].

Overall, our suggested diet may contribute to reducing the effects of the economic, health, and environmental crises in Lebanon and ultimately lead to the development of national Sustainable Food Based Dietary Guidelines (SFBDGs) for children. Given the increasing health, economic, and environmental challenges and pressures globally and locally, defining SFBDGs for children to firmly establish healthy and sustainable eating habits is necessary. SFBDGs can help improve children's health outcomes while contributing to environmental and economic security [60]. The findings of this study can help develop and reinforce public health nutrition policies and future interventions at multiple levels, including the marketing and provision of healthy and sustainable foods (within different environments), in addition to awareness campaigns and educational strategies targeting Lebanese children and their families. The methodology of the current study could also be adopted in other countries in the region that face the climate change-related environmental threats and a concomitant increase in diet-related NCDs. By deriving sustainable diets, countries can have "win-win" scenarios that take into consideration the needed trade-offs amongst context-specific socioeconomic, health, and environmental resources and conditions.

The present study has several strengths. To our knowledge, this study is the first to derive an optimally healthy and sustainable diet for Lebanese children that takes into consideration health, economic and environmental constraints and parameters while also devising culturally acceptable and contextually specific foods. Another strength of the study is the use of Optimeal, a diet optimization software that uses advanced mathematical techniques to derive diets based on complex parameters, and that has been validated and applied to date in several contexts [24,27–31]. Additional strengths include the use of the most recent 2015 dietary data, which present the actual national diet in Lebanon, as well as the use of 24 h dietary recalls, using the USDA multiple pass five-step approach, which was shown to reduce bias in nutrient and energy intake collection [61,62]. The study has a few limitations that are also worth noting. Although the social and cultural aspects of the food were considered during the diet optimization process in the present study, given that the food included was based on the national consumption data of Lebanese children, future studies are needed to further examine the cultural acceptability of the proposed optimized diets. As next steps, it is important to convene stakeholder meetings to build consensus and devise children-specific country-level SFBDGs that can take into consideration the children's own preferences and acceptability. Another limitation of the study is the exclusion of vitamin D as one of the nutrition/health constraints in the calculation of the optimized diet. This is due to the low amounts of vitamin D in naturally occurring foods and beverages and the limited fortification of vitamin D in dietary sources that are available in the Lebanese market [63]. Given the high prevalence for hypovitaminosis D in this context, measured at 32% in Lebanese girls and approximately 12% in Lebanese boys [64,65], vitamin D requirements would be mostly met through supplementation rather than food intake.

5. Conclusions

Lebanon represented a unique setting to conduct this study. The pressing economic, political, environmental, and health constraints that the country is witnessing have further exacerbated the food and nutrition security of its population, particularly vulnerable groups, including children and youth. Using a diet optimization approach, our study findings highlight dietary shifts that are needed to promote the health of children considering trade-offs between nutritional, and economic, environmental constraints, while also considering cultural and social acceptability. The resulting optimized diets highlight the need to increase the intakes of dark green vegetables, legumes and dairy products, and to reduce the consumption of red meats, processed meats, salty snacks, sweets, sugar-sweetened beverages, and saturated oils, as compared to the average national consumption. Such dietary shifts represent "win-win" scenarios that can help decrease costs and EFPs and satisfy health and nutritional needs for children of different age groups. Findings from this study can help decision makers and public health professionals devise evidence-base policies and programs to help alleviate food insecurity and mitigate further deterioration in the diets and health of children in Lebanon.

Finally, the UN Food Systems Summit 2021 along with other global efforts and campaigns are proposing radical transformations in our current food system(s) to promote more sustainable and nutritious diets that can meet the planetary boundaries and address the unprecedented challenges resulting from the COVID-19 health pandemic, climate change and conflicts. Our efforts in deriving sustainable diets that address the trade-offs among various dimensions of sustainability (health, environment, cost, and culture) represent a pragmatic and science-based approach to help shape policies, interventions, and consumer-based campaigns at various levels of the food system to keep us on track for achieving the sustainable development agenda.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su132313245/s1, Table S1: An overview of the food groups and the food items within each food group, Table S2: List of constraints for energy and nutrients used in the optimization calculations Ω, Table S3: Maximum constraints of environmental footprints (EFPs) and cost separated by age group.

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Informed Consent Statement: Written assent and informed consent were obtained from all individual participants (children and their caregivers) prior to their participation in the study.

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References

1. Food and Agriculture Organization of the United Nations (FAO). The Rome Declaration on World Food Security and World Food Summit Plan of Action. 1996. Available online: https://www.fao.org/3/w3613e/w3613e00.htm (accessed on 6 July 2021).
2. Food and Agriculture Organization of the United Nations (FAO). The State of Food Security and Nutrition in the World 2021: Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All. Available online: https://www.fao.org/3/cb4474en/cb4474en.pdf (accessed on 12 September 2021).
3. United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects 2019: Highlights. Available online: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf (accessed on 6 July 2021).
4. Burlingame, B.; Dernini, S. Sustainable Diets and Biodiversity Directions and Solutions for Policy, Research and Action. Available online: https://www.fao.org/3/i3004e/i3004e.pdf (accessed on 7 July 2021).
5. Kim, H.; Caulfield, L.E.; Garcia-Larsen, V.; Steffen, L.M.; Coresh, J.; Rebholz, C.M. Plant-Based Diets Are Associated With a Lower Risk of Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality in a General Population of Middle-Aged Adults. *J. Am. Heart Assoc.* **2019**, *8*, e012865. [CrossRef]
6. Satija, A.; Hu, F.B. Plant-Based Diets and Cardiovascular Health. *Trends Cardiovasc. Med.* **2018**, *28*, 437–441. [CrossRef]
7. Huang, T.; Yang, B.; Zheng, J.; Li, G.; Wahlqvist, M.L.; Li, D. Cardiovascular disease mortality and cancer incidence in vegetarians: A meta-analysis and systematic review. *Ann. Nutr. Metab.* **2012**, *60*, 233–240. [CrossRef] [PubMed]
8. Yokoyama, Y.; Nishimura, K.; Barnard, N.D.; Takegami, M.; Watanabe, M.; Sekikawa, A.; Okamura, T.; Miyamoto, Y. Vegetarian diets and blood pressure: A meta-analysis. *JAMA Intern. Med.* **2014**, *174*, 577–587. [CrossRef]
9. Glenn, A.J.; Lo, K.; Jenkins, D.J.A.; Boucher, B.A.; Hanley, A.J.; Kendall, C.W.C.; Manson, J.E.; Vitolins, M.Z.; Snetselaar, L.G.; Liu, S.; et al. Relationship Between a Plant-Based Dietary Portfolio and Risk of Cardiovascular Disease: Findings From the Women's Health Initiative Prospective Cohort Study. *J. Am. Heart Assoc.* **2021**, *10*, e021515. [CrossRef] [PubMed]
10. Jarmul, S.; Dangour, A.D.; Green, R.; Liew, Z.; Haines, A.; Scheelbeek, P.F. Climate Change Mitigation Through Dietary Change: A Systematic Review of Empirical and Modelling Studies on the Environmental Footprints and Health Effects of 'Sustainable Diets'. *Environ. Res. Lett.* **2020**, *15*, 123014. [CrossRef]
11. Goulding, T.; Lindberg, R.; Russell, C.G. The Affordability of a Healthy and Sustainable Diet: An Australian Case Study. *Nutr J.* **2020**, *19*, 109. [CrossRef] [PubMed]
12. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A. Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems. *Lancet* **2019**, *393*, 447–492. [CrossRef]
13. World Food Programme (WFP); United Nations High Commissioner for Refugees (UNHCR); United Nations International Children's Emergency Fund (UNICEF). Vulnerability Assessment of Syrian Refugees in Lebanon. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/VASyR%202020.pdf (accessed on 15 July 2021).
14. Bou Khater, L.; Majed, R. Lebanon's 2019 October Revolution: Who Mobilized and Why. Available online: http://www.activearabvoices.org/uploads/8/0/8/4/80849840/leb-oct-rev_-_v.1.3-digital.pdf (accessed on 15 July 2021).
15. Naja, F.; Hwalla, N.; El Zouhbi, A.; Abbas, N.; Chamieh, M.C.; Nasreddine, L.; Jomaa, L. Changes in Environmental Footprints Associated with Dietary Intake of Lebanese Adolescents between the Years 1997 and 2009. *Sustainability* **2020**, *12*, 4519. [CrossRef]
16. Nasreddine, L.; Naja, F.A.; Sibai, A.M.; Helou, K.; Adra, N.; Hwalla, N. Trends in Nutritional Intakes and Nutrition-Related Cardiovascular Disease Risk Factors in Lebanon: The Need for Immediate Action. *J. Med. Liban.* **2014**, *62*, 83–91. [CrossRef] [PubMed]
17. Poskitt, E.M. Countries in Transition: Underweight to Obesity Non-Stop? *Ann. Trop. Paediatr.* **2009**, *29*, 1–11. [CrossRef] [PubMed]
18. Nasreddine, L.; Hwalla, N.; Saliba, A.; Akl, C.; Naja, F. Prevalence and Correlates of Preschool Overweight and Obesity Amidst the Nutrition Transition: Findings from a National Cross-Sectional Study in Lebanon. *Nutrients* **2017**, *9*, 266. [CrossRef] [PubMed]
19. De Onis, M.; Blössner, M.; Borghi, E. Global Prevalence and Trends of Overweight and Obesity among Preschool Children. *Am. J. Clin. Nutr.* **2010**, *92*, 1257–1264. [CrossRef] [PubMed]
20. World Health Organization (WHO). Obesity and Overweight. Available online: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed on 21 August 2021).
21. Nasreddine, L.M.; Kassis, A.N.; Ayoub, J.J.; Naja, F.A.; Hwalla, N.C. Nutritional Status and Dietary Intakes of Children Amid the Nutrition Transition: The Case of the Eastern Mediterranean Region. *Nutr. Res.* **2018**, *57*, 12–27. [CrossRef] [PubMed]
22. Watson, J.F.; Collins, C.E.; Sibbritt, D.W.; Dibley, M.J.; Garg, M.L. Reproducibility and Comparative Validity of a Food Frequency Questionnaire for Australian Children and Adolescents. *Int. J. Behav. Nutr. Phys. Act.* **2009**, *6*, 62. [CrossRef] [PubMed]
23. Schwartz, C.; Scholtens, P.A.; Lalanne, A.; Weenen, H.; Nicklaus, S. Development of Healthy Eating Habits Early in Life. Review of Recent Evidence and Selected Guidelines. *Appetite* **2011**, *57*, 796–807. [CrossRef]
24. Brink, E.; van Rossum, C.; Postma-Smeets, A.; Stafleu, A.; Wolvers, D.; van Dooren, C.; Toxopeus, I.; Buurma-Rethans, E.; Geurts, M.; Ocké, M. Development of Healthy and Sustainable Food-Based Dietary Guidelines for the Netherlands. *Public Health Nutr.* **2019**, *22*, 2419–2435. [CrossRef]
25. Donati, M.; Menozzi, D.; Zighetti, C.; Rosi, A.; Zinetti, A.; Scazzina, F. Towards a Sustainable Diet Combining Economic, Environmental and Nutritional Objectives. *Appetite* **2016**, *106*, 48–57. [CrossRef]
26. Optimeal. Defining Sustainable Nutrition. Available online: https://www.optimeal.nl/ (accessed on 6 July 2021).

27. Broekema, R.; Tyszler, M.; van't Veer, P.; Kok, F.J.; Martin, A.; Lluch, A.; Blonk, H.T.J. Future-Proof and Sustainable Healthy Diets Based on Current Eating Patterns in the Netherlands. *Am. J. Clin. Nutr.* **2020**, *112*, 1338–1347. [CrossRef]
28. Kramer, G.F.H.; Martinez, E.V.; Espinoza-Orias, N.D.; Cooper, K.A.; Tyszler, M.; Blonk, H. Comparing the Performance of Bread and Breakfast Cereals, Dairy, and Meat in Nutritionally Balanced and Sustainable Diets. *Front. Nutr.* **2018**, *5*, 51. [CrossRef]
29. Kramer, G.F.H.; Tyszler, M.; Veer, P.v.t.; Blonk, H. Decreasing the Overall Environmental Impact of the Dutch Diet: How to Find Healthy and Sustainable Diets with Limited Changes. *Public Health Nutr.* **2017**, *20*, 1699–1709. [CrossRef]
30. Temme, E.H.M.; Bakker, H.M.E.; Seves, S.M.; Verkaik-Kloosterman, J.; Dekkers, A.L.; van Raaij, J.M.A.; Ocké, M.C. How May a Shift Towards a More Sustainable Food Consumption Pattern Affect Nutrient Intakes of Dutch Children? *Public Health Nutr.* **2015**, *18*, 2468–2478. [CrossRef] [PubMed]
31. Van Dooren, C.; Tyszler, M.; Kramer, G.F.H.; Aiking, H. Combining Low Price, Low Climate Impact and High Nutritional Value in One Shopping Basket through Diet Optimization by Linear Programming. *Sustainability* **2015**, *7*, 12837–12855. [CrossRef]
32. Vos, M.B.; Kaar, J.L.; Welsh, J.A.; Van Horn, L.V.; Feig, D.I.; Anderson, C.A.M.; Patel, M.J.; Cruz Munos, J.; Krebs, N.F.; Xanthakos, S.A.; et al. Added Sugars and Cardiovascular Disease Risk in Children: A Scientific Statement From the American Heart Association. *Circulation* **2017**, *135*, 1017–1034. [CrossRef] [PubMed]
33. Germani, A.; Vitiello, V.; Giusti, A.M.; Pinto, A.; Donini, L.M.; del Balzo, V. Environmental and Economic Sustainability of the Mediterranean Diet. *Int. J. Food Sci. Nutr.* **2014**, *65*, 1008–1012. [CrossRef] [PubMed]
34. National Academies of Sciences, Engineering, and Medicine. *Dietary Reference Intakes for Sodium and Potassium*; The National Academies of Sciences: Washington, DC, USA, 2019; pp. 565–580.
35. Jomaa, L.H.; Naja, F.A.; Kharroubi, S.A.; Diab-El-Harake, M.H.; Hwalla, N.C. Food insecurity is associated with compromised dietary intake and quality among Lebanese mothers: Findings from a national cross-sectional study. *Public Health Nutr.* **2020**, *23*, 2687–2699. [CrossRef] [PubMed]
36. Gidding, S.S.; Dennison, B.A.; Birch, L.L.; Daniels, S.R.; Gilman, M.W.; Lichtenstein, A.H.; Rattay, K.T.; Steinberger, J.; Stettler, N.; Van Horn, L. Dietary Recommendations for Children and Adolescents: A Guide for Practitioners: Consensus Statement from the American Heart Association. *Circulation* **2005**, *112*, 2061–2075. [CrossRef] [PubMed]
37. Hwalla, N.; Jomaa, L.; Hachem, F.; Kharroubi, S.; Hamadeh, R.; Nasreddine, L.; Naja, F. Promoting Sustainable and Healthy Diets to Mitigate Food Insecurity Amidst Economic and Health Crises in Lebanon. *Front. Nutr.* **2021**, *8*, 697225. [CrossRef]
38. Trumbo, P.; Schlicker, S.; Yates, A.A.; Poos, M. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. *J. Am. Diet. Assoc.* **2002**, *102*, 1621–1630. [CrossRef]
39. World Health Organization (WHO). Fats and Fatty Acids in Human Nutrition. Report of an Expert Consultation. Available online: https://www.fao.org/3/i1953e/I1953E.pdf (accessed on 20 July 2021).
40. Mahadevan, K. Chapter—Seaweeds: A Sustainable Food Source. In *Seaweed Sustainability*; Tiwari, B.K., Troy, D.J., Eds.; Academic Press: San Diego, CA, USA, 2015; pp. 347–364.
41. Ministry of Economy and Trade (MoET). Monthly Price Movement Report—January. Available online: http://www.economy.gov.lb/media/12700/jan2020.pdf (accessed on 7 July 2021).
42. Naja, F.; Itani, L.; Hamade, R.; Chamieh, M.C.; Hwalla, N. Mediterranean Diet and its Environmental Footprints Amid Nutrition Transition: The Case of Lebanon. *Sustainability* **2019**, *11*, 6690. [CrossRef]
43. Naja, F.; Jomaa, L.; Itani, L.; Zidek, J.; El Labban, S.; Sibai, A.M.; Hwalla, N. Environmental Footprints of Food Consumption and Dietary Patterns among Lebanese Adults: A Cross-Sectional Study. *Nutr. J.* **2018**, *17*, 85. [CrossRef]
44. Khalil, Z.; Naja, F.; Jomaa, L.; Bahn, R.; Hwalla, N. *The Economic Cost and Environmental Impacts of Shifting to Healthier Dietary Patterns in Lebanon*; American Univeristy of Beirut: Beirut, Lebanon, 2020; manuscript in preparation.
45. Jomaa, L.; Hamamji, S.; Kharroubi, S.; Diab-El-Harakeh, M.; Al Zahraa Chokor, F.; Nasreddine, L. Dietary Intakes, Sources, and Determinants of Free Sugars Amongst Lebanese Children and Adolescents: Findings from Two National Surveys. *Eur. J. Nutr.* **2021**, *60*, 2655–2669. [CrossRef] [PubMed]
46. United States Department of Agriculture (USDA). Dietary Guidelines for Americans, 2020–2025. Available online: https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf (accessed on 21 August 2021).
47. Fresán, U.; Sabaté, J. Vegetarian Diets: Planetary Health and Its Alignment with Human Health. *Adv. Nutr.* **2019**, *10*, 380–388. [CrossRef] [PubMed]
48. Nelson, M.E.; Hamm, M.W.; Hu, F.B.; Abrams, S.A.; Griffin, T.S. Alignment of Healthy Dietary Patterns and Environmental Sustainability: A Systematic Review. *Adv. Nutr.* **2016**, *7*, 1005–1025. [CrossRef] [PubMed]
49. Simpson, V.; Pedigo, L.; Hamdan Rodriguez, M. Healthy Food Access and Low-Income Teens: A Photovoice Approach. *West. J. Nurs. Res* **2021**, *43*, 542–550. [CrossRef] [PubMed]
50. Lee, A.; Patay, D.; Herron, L.-M.; Harrison, E.P.; Lewis, M. Affordability of Current, and Healthy, More Equitable, Sustainable Diets by Area of Socioeconomic Disadvantage and Remoteness in Queensland: Insights into Food Choice. *Int. J. Equity Health* **2021**, *20*, 1–17. [CrossRef] [PubMed]
51. Andrieu, E.; Darmon, N.; Drewnowski, A. Low-Cost Diets: More Energy, Fewer Nutrients. *Eur. J. Clin. Nutr.* **2006**, *60*, 434–436. [CrossRef] [PubMed]
52. Hirvonen, K.; Bai, Y.; Headey, D.; Masters, W.A. Affordability of the EAT–Lancet Reference Diet: A Global Analysis. *Lancet Glob. Health* **2020**, *8*, 59–66. [CrossRef]

53. Kirk, B.; Melloy, B.; Iyer, V.; Jaacks, L.M. Variety, Price, and Consumer Desirability of Fresh Fruits and Vegetables in 7 Cities around the World. *Curr. Dev. Nutr.* **2019**, *3*, nzz085. [CrossRef] [PubMed]
54. Locke, E.; Coronado, G.D.; Thompson, B.; Kuniyuki, A. Seasonal Variation in Fruit and Vegetable Consumption in a Rural Agricultural Community. *J. Am. Diet. Assoc.* **2009**, *109*, 45–51. [CrossRef]
55. Ministry of Economy and Trade (MoET). Weekly Basket Report- October. Available online: https://www.economy.gov.lb/en/services/center-for-pricing-policies/mini---basket-weekly- (accessed on 7 July 2021).
56. Human Rights Watch. World Report 2021: Events of 2020. Available online: https://www.hrw.org/sites/default/files/media_2021/01/2021_hrw_world_report.pdf (accessed on 19 September 2021).
57. Abi-Rached, J.; Diwan, I. The Socioeconomic Impact of COVID-19 on Lebanon: A Crisis Within Crises. Available online: https://www.euromesco.net/publication/the-socioeconomic-impact-of-covid-19-on-lebanon-a-crisis-within-crises/ (accessed on 3 September 2021).
58. United Nations International Children's Emergency Fund (UNICEF). Lebanon: Children's Future on the Line. Available online: https://www.unicef.org/lebanon/media/6541/file (accessed on 19 September 2021).
59. Kharroubi, S.; Naja, F.; Diab-El-Harake, M.; Jomaa, L. Food Insecurity Pre- and Post the COVID-19 Pandemic and Economic Crisis in Lebanon: Prevalence and Projections. *Nutrients* **2021**, *13*, 2976. [CrossRef] [PubMed]
60. Hollis, J.L.; Collins, C.E.; DeClerck, F.; Chai, L.K.; McColl, K.; Demaio, A.R. Defining Healthy and Sustainable Diets for Infants, Children and Adolescents. *Glob. Food Sec.* **2020**, *27*, 100401. [CrossRef]
61. Blanton, C.A.; Moshfegh, A.J.; Baer, D.J.; Kretsch, M.J. The USDA Automated Multiple-Pass Method Accurately Estimates Group Total Energy and Nutrient Intake. *J. Nutr.* **2006**, *136*, 2594–2599. [CrossRef] [PubMed]
62. Moshfegh, A.J.; Rhodes, D.G.; Baer, D.J.; Murayi, T.; Clemens, J.C.; Rumpler, W.V.; Paul, D.R.; Sebastian, R.S.; Kuczynski, K.J.; Ingwersen, L.A.; et al. The US Department of Agriculture Automated Multiple-Pass Method Reduces Bias in the Collection of Energy Intakes. *Am. J. Clin. Nutr.* **2008**, *88*, 324–332. [CrossRef] [PubMed]
63. Malaeb, D.; Hallit, S.; Salameh, P. Assessment of Vitamin D Levels, Awareness among Lebanese Pharmacy Students, and Impact of Pharmacist Counseling. *J. Epidemiol. Glob. Health* **2017**, *7*, 55–62. [CrossRef]
64. Wahl, D.A.; Cooper, C.; Ebeling, P.R.; Eggersdorfer, M.; Hilger, J.; Hoffmann, K.; Josse, R.; Kanis, J.A.; Mithal, A.; Pierroz, D.D.; et al. A Global Representation of Vitamin D Status in Healthy Populations. *Arch. Osteoporos.* **2012**, *7*, 155–172. [CrossRef] [PubMed]
65. El-Hajj Fuleihan, G. Vitamin D Deficiency in the Middle East and Its Health Consequences for Children and Adults. *Clin. Rev. Bone Miner. Metab.* **2009**, *7*, 77–93. [CrossRef]