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A Sustainable and Global Health Perspective of the Dietary Pattern of French Population during the 1998–2015 Period from INCA Surveys

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Abstract: In France, the evolution of dietary pattern relative to sustainability and global health remains insufficiently studied. The objective of this study was to assess dietary changes during 1998–2015 through three generic metrics potentially related to sustainability. Food consumption data were collected from three French National Individual Study of Food Consumption surveys (INCA) for children (0–17 years) and adults (18–79 years) representative of the French population. The consumed foods were converted into plant (metric 1) and non-ultra-processed (UPF, metric 2) calories, and analyzed in meeting dietary recommended intakes (metric 3). French children and adults consumed high levels of animal and UPF calories, and nutrient deficiencies were observed in adults from the 2015 survey, e.g., fiber, EPA, DHA, magnesium, retinol, and vitamin C. In children, UPF daily calories increased from 42.8 to 45.5% and decreased in adults from 39.2 to 35.0%. In children and adults, diet revegetation was observed. While the level of physical activity decreased, overweight, obesity and type 2 diabetes prevalence increased in French adults. The French dietary pattern is not sustainable for global health unless public health policy is reinforced, with at least a twofold decrease in animal and UPF calories and improved food diversity.

Keywords: sustainability; global health; French dietary pattern; animal products; ultra-processed foods; nutritional needs

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1. Introduction

Western countries, including France, have faced an important nutrition transition for the last seven decades, i.e., after the Second World War, nutrition began to be characterized by a progressive increase in animal and ultra-processed food (UPF) product consumption [1–4]. This transition is now at work in emerging countries such as Brazil [5], some Southeast Asian countries [6,7], and China [8] and is emerging in developing countries such as those in Africa [9]. Paralleling this transition, a dramatic increase in the prevalence of chronic diseases has been observed in Western countries, progressively replacing that of infectious diseases, but at a higher rate than in low- and middle-income countries [10–12]. Thus, in 2016–2017, worldwide deaths from noncommunicable diseases represented 72.3% of all deaths [12,13], for which the three main leading and combined triggering factors were malnutrition (both over- and undernutrition and/or nutritional deficiencies), environmental pollution, and physical inactivity [14]. Dietary risk factors alone would cause nearly 11 million premature deaths worldwide [15]. The increasing consumption of industrialized "empty" calories [16–19], reflecting a high level of UPF consumption [20], may also be accompanied by the appearance of deficiencies of fiber and micronutrients such as iron [21],

iodine [22], magnesium [23], calcium [24], and vitamins B12 [25,26] and D [27]. Moreover, this typical Western diet has been repeatedly reported to be unsustainable for global health, compromising human health [28–38], in addition to environmental issues, animal well-being and biodiversity, socioeconomics, culinary traditions, and the disappearance of small farmers worldwide [39–44]. Furthermore, food systems overall contribute to 34% of total greenhouse gas emissions [45].

Previous works have been undertaken to identify quantifiable criteria or model future scenarios to optimize the links between diet and global health [46–50]. Based on published studies related to diets, human health, and food system sustainability, three inductive, generic, and interconnected dimensions were proposed to govern the diet–global health relationship worldwide, leading to the concept of the 3V index that includes the degree of food processing (Vrai/Real foods: 15% maximum UPF calories/day), the plant/animal product ratio (Végétal/Plant foods: 15% maximum animal calories/day), and food diversity (Varié/Varied foods) [40,51]. This generic index represents both qualitative and quantitative holistic metrics regarding human health and food system sustainability. Knowing the evolution of a dietary pattern in a specific population toward these three metrics, therefore, appears to be a simple and relevant tool for evaluating the global health potential of dietary habits over time.

The evolution of the French dietary pattern toward these three indicators remains to be evaluated. This might indeed provide relevant information for national public health strategy aiming at both reducing greenhouse gas emissions and the prevalence of chronic diseases while improving food system sustainability at Horizon 2050, as proposed by scenarios of the French foresight project, Agrimonde-Terra, which includes animal and UPF products as potential drivers [47].

Approximately every seven years, the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) carries out a representative survey (i.e., survey: National Individual Study of Food Consumption (INCA)) of the dietary habits of French people in different age groups [52–54]. The three surveys were carried out in 1998–1999, 2006–2007, and 2014–2015 with open and available data regarding food consumption. The main objective of the present study was to evaluate the evolution of the health and sustainable potentials of the French dietary pattern during 1998–2015 based on the newly developed global health-related 3V index. Our second objective was to relate this evolution to overweight/obesity and type 2 diabetes prevalence during the same period. The main conclusion is that the French dietary pattern between 1998 and 2015 was not sustainable and protective against global health, with at least 35% daily animal and UPF calories, and some nutrient deficiencies.

2. Materials and Methods

2.1. Data and Study Population

2.1.1. Data Collection

Data for food consumption (g/day), overweight/obesity prevalence, and level of physical activity by age group were collected from the three INCA reports [55–57] (also available at https://www.anses.fr/fr/content/les-%C3%A9tudes-inca (accessed on 18 February 2021)). In 1998–1999, data for overweight/obesity prevalence were lacking in the INCA1 survey and were retrieved from other French national health sources [58,59]. The evolution of type 2 diabetes prevalence (%) in the overall French population (children and adults included) during the 1992–2019 period was assessed from Fosse-Edorh et al. [60], Fagot-Campagna et al. [61], ANAES (Agence nationale d'accréditation et d'évaluation en santé) [62], Fuentes et al. [63], and Santé Publique France [64].

2.1.2. Study Population

The INCA surveys followed a cross-sectional design. INCA populations were sampled to be representative of the French population, e.g., living in mainland France, and followed a multistage stratified random sampling method using the national census database [52–54].

Age groups differ between the three INCA surveys. In INCA1 (1998–1999), children are 3–14 years old (n = 1016) and adults 15–75 years old (n = 1423) [57]; in INCA2 (2006–2007), children are 3–17 years old (n = 1444) and adults 18–79 years old (n = 1918) [56]; in INCA3 (2014–2015), children are 1–10 (n = 1035) and 11–17 (n = 949) years old, and adults are 18–79 years old (n = 2121) [55].

2.2. Data Processing for the 3 V Index

The qualitative and quantitative aspects of the 3V index-based metrics have been previously thoroughly described [40,51]. To assess the evolution of plant/animal and non-UPF/UPF calorie consumption during the 1998–2015 period, INCA food categories (g/day) were converted into calories. Except for INCA1 (1998–1999), the calories consumed per day were given in INCA2 and INCA3 for each food category and age group. For INCA1, a median calorie content/100 g was calculated based on the French Ciqual database for each of the 32 INCA1 food categories (Supplementary Materials Table S1) [65]. For this analysis, all as-eaten foods were recorded. For example, in the INCA1 "mixed dishes" category, 145 eaten foods were reported for calorie content, and a median value of 141 kcal/100 g was calculated (Supplementary Materials Table S1). According to food products presented in the Ciqual database, the number of selected foods for each INCA1 category differs. For children in INCA3, the plant, animal, non-UPF, and UPF calorie percentages were averaged for the two age groups, i.e., 1–10 years and 11–17 years.

2.2.1. Metric 1: "Végétal" (Plant-Based Foods)

The percentages of animal and plant calories in each INCA survey and for each food category are presented in Supplementary Tables S1–S3. For combined products containing ingredients of both animal and plant origin, recipes were collected on a French website dedicated to more than 7000 recipes (https://www.marmiton.org/ (accessed on 20 March 2021)) for the preferred food products consumed by the French population. Overall, the three main recipes characteristic of each of the INCA categories were considered and converted into animal and plant calories. In the INCA3 survey, categories are sometimes a combination of previous categories of INCA1 and INCA2. For example, the INCA3 "pasta, rice, wheat, and other grains" category was a combination of the INCA2 "pasta", "rice and durum or cracked wheat" and "other cereals" categories. In such cases, the number of recipes in INCA3 for a given category was the sum of INCA2 or INCA1 categories, explaining why there was a higher number of selected recipes, i.e., up to 13 (Supplementary Table S3).

2.2.2. Metric 2: "Vrai" (Non-UPF/Real Foods)

The percentage of UPF calories in the INCA1-3 surveys was assessed based on the Siga score according to the degree of processing [66]. First, the percentages of UPFs in each INCA food category were imputed from the UPF percentages in 127 Siga categories (n = 47,358 food products) that were matched with INCA categories (n = 32 categories for INCA1, n = 43 categories for INCA2, and n = 44 categories for INCA3 with the supplemental "infant milk and beverages" category compared to INCA2). However, UPF percentages by Siga category only concerned industrially labeled packaged foods and did not include fresh and bulk foods. Therefore, in a second analysis, we applied a weighting factor to percentages of UPF calories per INCA category based on the percentages of industrial foods consumed among either all foods or each category: (1) for INCA1 in 1998–1999 and INCA2 in 2006–2007, the percentages of consumed industrial foods were not provided in the reports and were therefore evaluated from expenses for industrial foods, i.e., 84% in 2000 and 83% in 2006, respectively [67]; (2) for INCA3 in 2014–2015, we based the weighting on the reported percentages among 12 food categories of homemade dishes, industrial foods, artisanal foods, fast foods and other purchasing places (main INCA3 report, n = 18,857 acts of consumption for the 0–17 age group and n = 15,393 acts of consumption for the 18–79 age group), and on reported consumption frequencies for homemade dishes, industrial foods, artisanal foods, collective catering, fast food and

vending machine items for the 31 other food categories (INCA3 supplemental material entitled "Thesaurus/Descriptors", n = 86,113 acts of consumption) [55].

2.2.3. Metric 3: "Varié" (Varied Foods)

The degree of food diversity was indirectly evaluated from two indicators: (1) the evolution of adequacy in meeting the DRI for free sugar (i.e., sugars from honey, added sugars, and fruit juices), fiber, EPA, DHA, salt, saturated fatty acids, minerals, trace elements and vitamins; (2) the evolution of calorie shares for 15 nutrient-dense food groups representative of food pyramids: bread and dry breadmaking; pasta, rice, and semolina; milk; ultra-fresh dairy; cheeses; eggs and derivatives; meats; poultry and game; fish, crustaceans and mollusks; vegetables (except potatoes); potatoes and their derivatives; legumes; fruits; nuts, seeds, and oleaginous fruits; and offal. The adequacy in meeting nutritional needs was only calculated for adults since, in the 0–17 age group, the DRI evolved from one year to the next. Finally, the adequacy in meeting the DRI in the INCA1 survey has been evaluated by Dubuisson et al. [54], although data are lacking for intake of free sugars, EPA, DHA, salt, magnesium, phosphorus, potassium, manganese, copper, zinc, selenium, iodine, retinol, vitamins B1–B6, vitamin B12, and vitamins D and E.

2.3. Data Analyses

The results were expressed as animal/plant and non-UPF/UPF calorie percentages by INCA food category and summed to obtain the overall plant and non-UPF calories consumed daily in each age group for the three INCA surveys. Nutritional needs were expressed as percentages of the DRI.

3. Results

Between 1998 and 2015, total calorie consumption in the adult population slightly decreased (by 7.5%), while remaining stable for children at approximately 1767 kcal/day (Table 1).

Table 1. Daily plant and UPF calorie percentages, level of low physical activity, and overweight/obesity prevalence for the three French INCA surveys.

	INCA1 (1998–1999)	INCA2 (2006–2007)	INCA3 (2014–2015)	INCA1 (1998–1999)	INCA2 (2006–2007)	INCA3 (2014–2015)
	Children (0–17 [1])			Adults (18 [1]–79)		
Kcal/day	1759	1777	1765	2285	2162	2114
Minimally processed food category calorie (%) [2]	47.2	42.8	41.7	49.4	48.0	48.9
Plant calories (%)	54.5	56.2	61.2	59.6	59.7	64.1
Real food (i.e., non-UPF) calories (%)	57.2	56.8	54.5	60.8	59.8	65.0
Low level of physical activity (%)	- [3]	20	38	- [3]	25	37
Overweight (%)	15 [4]	14	17	30 [4]	43	51
Obesity (%)	4 [2]	3	4	9 [4]	12	17

[1] Age thresholds vary according to INCA surveys; [2] For 15 nutrient-dense food groups representative of food pyramids, i.e., bread and dry breadmaking; pasta, rice, and semolina; milk; ultra-fresh dairy; cheeses; eggs and derivatives; meats; poultry and game; fish, crustaceans and mollusks; vegetables (except potatoes); potatoes and their derivatives; legumes; fruits; nuts, seeds and oleaginous fruits; and offal; [3] data not available; [4] data from [58].

3.1. Adequacy Level in Meeting the 3 V Index

In children (0–17 years), while the level of daily plant calories (metric 1) increased from 55 to 61% between 1998 and 2015 (i.e., an increase of 11%), that of daily non-UPF calories (metric 2) decreased from 57 to 55% (i.e., a decrease of 4.7%) (Table 1). In adults, during the same period, daily plant calories increased from 61% to 65% (i.e., +7.6%), and non-UPFs increased from 61 to 68% (i.e., +6.9%) (Table 1).

Concerning adequacy in meeting the DRI, the percentages of free sugars and saturated fatty acids (as calories) were above the recommended 10% and 12% of total daily calories,

respectively (Table 2). In 2015, salt consumption was 167% above the DRI of 5 g/day, and sodium consumption was also at least 156% above the DRI during the 1998–2015 period. Similarly, fiber consumption was 29, 42, and 34% below the DRI for the INCA1, INCA2, and INCA3 surveys, respectively. Concerning micronutrients, phosphorus, potassium, calcium, manganese, iron, selenium, copper, zinc, and vitamins B2, B3, B5, B6, B12, D (80% of vitamin D is supplied by sun exposure) and E met the DRI overall, while this was not the case for magnesium, iodine, retinol, and vitamins B1 and C.

Table 2. Adequacy in meeting the DRI in the French adult population during 1998–2015.

			INCA1	INCA2	INCA3
Nutrients	**Unit**	**DRI/Day**		**% DRI**	
Free sugars	g	10% calories max	- [1]	12	13
Fiber	10% kcal	30	71	58	66
EPA	mg	250	-	-	47
DHA	mg	250	-	-	68
Salt	g	5	-	-	160
SFA	12% kcal	12% calories max	15	14	13
Sodium	mg	1900	168	156	167
Magnesium	mg	420	-	69	81
Phosphorus	mg	700	-	181	177
Potassium	mg	2000	-	148	155
Calcium	mg	900	95	102	103
Manganese	mg	3	-	104	111
Iron	mg	11	119	119	95
Copper	mg	1	-	115	131
Zinc	mg	8	-	143	127
Selenium	mg	70	-	76	179
Iodine	mg	150	-	84	99
Retinol	mg	750	-	94	63
Vitamin B1	mg	1	-	92	92
Vitamin B2	mg	2	-	106	100
Vitamin B3	mg	17	-	107	118
Vitamin B5	mg	6	-	97	98
Vitamin B6	mg	2	-	94	94
Vitamin B9	mg	330	80	87	92
Vitamin B12	mg	4	-	145	135
Vitamin C	mg	110	70	84	82
Vitamin D	mg	15	-	17	21 [2]
Vitamin E	mg	11	-	110	93

[1] Data not available; [2] supposedly, 80% of vitamin D is supplied by sun exposure; NB: values in red do not match the DRI. Abbreviations: DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.

Daily calories from food pyramid-based INCA categories decreased in children by ≈9% and remained stable in adults around 49% (Table 1). Therefore, in contrast to adults, children tended to consume fewer daily food pyramid-based INCA categories between 1998 and 2015 (i.e., −12%), mainly deriving from reduced daily consumption of bread and dry bread making, milk, meats, potatoes and derivatives, cheeses, poultry, and fruits (Table 3). In adults, there was both an increase in plant-derived food groups (e.g., pasta, rice, and semolina, fruits and vegetables) and a decrease in the animal-derived group (e.g., cheeses, meats, and milk) in some INCA categories (Table 3).

Table 3. Percentages of consumed calories per day from food minimally processed pyramid-based groups in children and the adult French population during 1998–2015 based on the INCA1-3 surveys.

	INCA1 (1998–1999)	INCA2 (2006–2007)	INCA3 (2014–2015)	INCA1 (1998–1999)	INCA2 (2006–2007)	INCA3 (2014–2015)
	Children (0–17 [1])			Adults (18 [1]–79)		
Bread and dry breadmaking	10.0	9.3	8.7	15.3	14.7	15.4
Milk	5.9	5.0	3.3	5.6	5.1	4.8
Pasta, rice, and semolina	4.8	4.4	5.4	4.7	4.5	4.2
Meats	4.8	4.4	3.7	3.7	3.4	4.1
Potatoes and their derivatives	4.3	3.7	2.5	3.5	3.2	3.1
Cheeses	4.1	3.5	3.2	3.2	3.3	3.4
Ultra-fresh dairy	3.9	3.7	4.4	3.1	2.7	2.2
Poultry and game	2.8	2.0	2.1	2.9	2.9	3.1
Fruits	2.6	2.0	2.3	2.5	2.0	1.6
Fish, crustaceans, and mollusks	1.4	1.7	1.5	1.6	2.0	1.9
Vegetables (except potatoes)	1.3	1.4	1.6	1.6	1.9	2.6
Eggs and derivatives	0.9	1.0	1.1	1.2	1.2	1.1
Legumes	0.4	0.4	1.6	0.5	0.4	0.4
Nuts, seeds, and oleaginous fruits	- [2]	0.2	0.2	- [2]	0.5	0.7
Offal	- [2]	0.1	0.1	- [2]	0.2	0.3
Total	47.2	42.8	41.7	49.4	48.0	48.9

[1] Age thresholds vary according to INCA surveys; [2] data not available from INCA1 survey.

3.2. The Evolution of the Prevalence of Overweight, Obesity, Type 2 Diabetes, and Physical Activity

During 1998–2015, the prevalence of overweight increased in adults from 30 to 51% and was relatively stable for children around 14–17% (Table 1). Concomitantly, the following step of obesity prevalence remained stable in children at approximately 3–4%, whereas it almost doubled in adults from 9 to 17%. Importantly, the percentage of children and adults with a low level of physical activity increased between 2006 and 2015, i.e., from 20 to 38% (i.e., almost doubled) and from 25 to 37%, respectively, and the type 2 diabetes prevalence consistently and linearly increased during 1998–2015, i.e., from 2.6 to 5.0%, which corresponded to an increase of 92% (Figure 1). Finally, in adults between 1998 and 2015, plant and non-UPF calorie shares, a low level of physical activity (%), overweight, obesity, and type 2 diabetes prevalence all increased together. Among children, the non-UPF calorie percentage decreased, while obesity and overweight prevalence remained quite unchanged (Table 1).

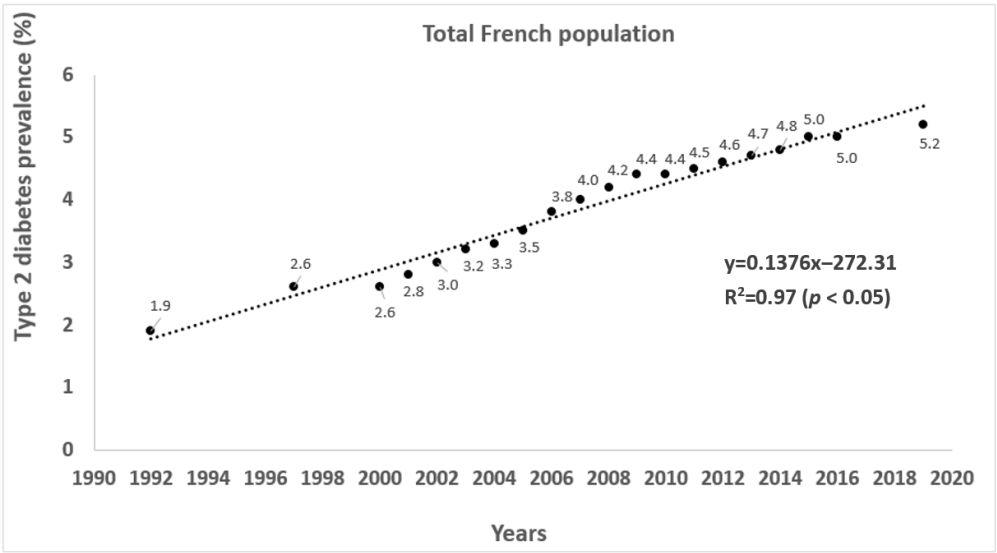

Figure 1. Evolution of type 2 diabetes prevalence (%) in the French population (children and adults included) during 1992–2019.

4. Discussion

Between 1998 and 2015, daily total caloric consumption either decreased in adults or remained constant in children, which does not appear, at first view, to be in agreement with the regular increase in overweight, obesity, and type 2 diabetes prevalence in adults, suggesting that the quality, rather than the quantity, of calories may be involved. In this study, this has been addressed through the lens of the global health-based 3V index.

4.1. Adequacy in Meeting the 3V Index

The evolution of the French dietary pattern during 1998–2015 first showed progressive revegetation of the plate/meals in both children and adults. In children, the decrease in animal product consumption had already been emphasized in a comparison of the INCA1 and INCA2 surveys [53]. In both children and adults, animal calorie consumption is still above that recommended by the French National Program Nutrition and Health (PNNS), which corresponds to approximately 23–30% of daily calories [40]. For UPF calorie consumption in the last 2015 INCA survey, the level found in adults, i.e., 35%, was close to the data from the French cohort Nutrinet study, i.e., 35.9% UPF calories [68], and that recently found for the same INCA population as in our study, but using the NOVA classification, i.e., 30.6% [69].

Moreover, while children regularly increased their consumption of UPF calories between 1998 and 2015, adults decreased their consumption, especially in 2015, with an 11% lower intake than that of children. Such differences between children and adults were also observed in other countries, such as Canada (55 versus 47%) [70] and Brazil (46–47 versus 26%) [71–73]. Higher UPF consumption by children may result from aggressive and efficient targeting of food marketing, as already observed in Argentina [74] and Latin America, where UPF advertising, especially beverages, is poorly regulated [75]. In addition, a Swedish study reported that a "high proportion of UPF advertisements is concerning and is in sharp contrast to the Swedish dietary guidelines that recommend reduced consumption of such foods" (page 1) [76]. Furthermore, this suggests that many UPFs that are available in food markets target young children, probably leading parents to buy these foods to please their children. Despite the poor availability of data regarding the level of UPF purchases in French food markets specifically for children, it has been observed in Norway that, based on sales and barcode data, UPF represented 59% of purchases [77], and in Uruguay, the references to "homemade" and "natural foods" on the labels of UPFs (i.e., a false "health halo") falsely increase the perception of healthfulness and thus purchase intention [78]. In the USA, it has also been observed that low-income households with children selected UPFs because of their familiarity and long shelf life, two attributes that mitigated the fear of wasting money on foods that may be rejected by children or spoil quickly [79].

Food diversity may be indirectly assessed by the adequacy in meeting the DRI and the calorie shares of fresh or minimally processed food groups that are more nutrient-dense than UPFs. In children, this percentage changed from 47% in 1999 to 42% in 2015, in agreement with the higher consumption of UPFs and more generally, industrial foods, as reported by the INCA3 report [55]. From these observations, it may be hypothesized that if children consume more plant-based foods, they are also probably more ultra-processed. Thus, in France, higher avoidance of animal-based foods was notably recently associated with higher consumption of plant-based UPFs, supplying 33.0%, 32.5%, 37.0%, and 39.5% of the calorie intake for meat eaters, pesco-vegetarians, vegetarians, and vegans, respectively [80]. Within the INCA surveys from 1998 to 2015, together with a relatively high level of low nutritional density UPF consumption, an insufficient DRI adequacy for salt, DHA, EPA, fiber, magnesium, and some vitamins might suggest an insufficient level of food diversity in the French adult population.

4.2. Association with Chronic Disease Prevalence

The high level of animal and UPF calorie consumption and a likely moderate level of food diversity, together with an important increase in low levels of physical activity, might explain the regular increase in overweight, obesity, and type 2 diabetes prevalence in the French adult population despite revegetation of the plate and a slight decrease in UPF consumption, which therefore remains insufficient to prevent these chronic metabolic dysregulations. Paradoxically, in French children, the significant increase in UPF consumption from 1998 to 2015 did not seem to have a significant impact on obesity and overweight prevalence, although there was an increase in the percentage of children with a low level of physical activity from 20 to 38% between 2006 and 2015. An explanation could be that chronic diseases usually appear in adulthood, which may explain why there is no increase in children as regards to overweight/obesity prevalence, indicating that an improvement in the quality of the diet during childhood could result in a decrease in the prevalence of obesity and type 2 diabetes in adults.

These observations in adults are not surprising with regard to previous data about UPF consumption and overweight/obesity prevalence, i.e., a significant association was identified between UPF intake and obesity with a UPF calorie share below those observed in this study [81]. In a previous ecological study in 19 European countries, each percentage point increase in the household availability of UPFs resulted in an increase of 0.25 percentage points in obesity prevalence [82]. In a Brazilian longitudinal study, weight gain and incident overweight or obesity linearly increased between 0.5 and 30% UPF calories and then plateaued [83]. The association between excess animal and UPF calorie consumption and overweight, obesity, and type 2 diabetes prevalence is rather problematic from a public health point of view because these first steps of metabolic dysregulations are well known to increase the risk of more severe chronic diseases such as cardiovascular diseases, and some malnutrition-related cancers [84].

Therefore, the question arises whether a sufficient level of physical activity might prevent the deleterious health impact of UPFs. Notably, in healthy, young Canadian men, it was reported that high-intensity interval training may protect against the effects of an exclusive 14-day fast food diet on the cardiometabolic profile (i.e., lipids, hepatic enzymes, glycated hemoglobin, glucose, insulin, hsC-reactive protein, and blood pressure) [85]. However, it remains unknown whether it is sufficient to prevent the occurrence of chronic disease in the long term when consuming large amounts of fast foods/UPFs. It appears that in American children (i.e., studies of the United States of America National School Lunch and School Breakfast Programs), school diet- and physical activity-related policies, when implemented together, may prevent or treat overweight or obesity [86]. In another cross-sectional Chinese study in adults, individuals with active physical activity levels and an unhealthy diet had a similar risk of a high TG/HDLC ratio to those with inactive physical activity levels and a healthy diet [87], suggesting that further long-term studies are necessary to confirm the benefits of physical exercise as reversing the unfavorable metabolic impacts of unhealthy foods, including UPFs.

4.3. Impact of the French Programme National Nutrition Santé

Since 2001, the French Ministry of Health has implemented the Programme National Nutrition Santé (PNNS), with the main objective of improving the overall health status of the French population, especially to reduce overweight and obesity prevalence, through the main determinant of nutrition [88]. It has been notably based on the promotion of physical activity ("eat–move", "at least the equivalent of 30 min of brisk walking per day"), the promotion of fruit and vegetable consumption ("five fruits and vegetables per day"), and a reduction in salted, sweet and fatty product consumption. More recently, in the last PNNS4 (2019–2023), the use of a compositional score ("Nutri-score") has been made mandatory while recommending reducing UPF consumption by 20% by 2023 [89]. At the same time, specific programs on knowledge and practices were applied in French schools (aged 6–18) but with variable intensity according to places and time. Although this study

has not been intended to evaluate the impact of the French PNNS, the continuous increase in the prevalence of obesity and type 2 diabetes in adults between 1998 and 2015 indicates a need to strengthen public health policy for physical activity, and with a particular focus on the degree of processing of industrially packaged foods and a stronger reduction in animal-based foods to reach a more sustainable French diet.

4.4. Limitations of the Study

The main limitation of the study is the approximations made for the calculation of the UPF percentages, especially for the INCA1 and INCA2 surveys. The values were based on UPF percentages from Siga categories and applied to the INCA food category. Indeed, it is likely that UPF percentages by category have evolved during 1998–2015. However, in Western countries, it is assumed that UPF sales have sharply risen since the 1980's to culminate in the 1990's [90], suggesting that the level of UPF availability has remained quite stable thereafter, as confirmed by a reported compounding annual growth rate close to 0% in France between 2009 and 2019 [1]. The other approximation was the percentages of industrial foods consumed by French people in 2000 and 2006, which were based on expenses, not on the quantity consumed [67]. However, with industrial (energy-dense) foods being generally cheaper than fresh and/or raw foods, these values have been considered to represent the minimum percentage of consumed industrial foods. Taken together, these considerations suggest that the UPF share of French children and adults in 1998–1999 and 2006–2007 might have been slightly underestimated rather than overestimated. The second main limitation is related to the ecological nature of this study that only shows associations and/or correlations, not a causal relationship. However, it has been established that the three main common modifiable risk factors involved in the development of chronic diseases worldwide are unhealthy diet, physical inactivity, and tobacco use [14]. In this study, the first two factors have been considered, suggesting a relevant potential association with the observed increases of overweight/obesity and type 2 diabetes prevalence in France, even if not causality.

5. Conclusions

A high level of daily animal and UPF calorie shares, an insufficient level of food diversity, and an increased level of low physical activity constitute favorable grounds for the increased prevalence of metabolic dysregulations, as has been constantly observed in many Western countries. More generically, it seems that the more a population moves away from the 3V index, particularly if associated with a low level of physical activity, the more the overweight/obesity and type 2 diabetes prevalence increases. In addition, simply meeting the nutrient DRI does not appear sufficient for consuming a healthy diet; the quality of calories also matters. Indeed, while the French adult population slightly decreased its total daily calorie consumption, overweight, obesity, and type 2 diabetes prevalence importantly increased, suggesting that the quality of their calories worsened rather than the quantity. This quality, expressed in the 3V metrics by their origin (i.e., plant versus animal) and degree of processing (non-UPF versus UPF), appears to better explain the diet–health relationship.

Therefore, the French dietary pattern is far from being sustainable, with daily animal and UPF calorie consumption largely above the optimum thresholds of 15% [40], suggesting that French children and adults should decrease their daily animal and UPF calorie consumption by at least twofold in favor of mildly processed plant-based foods to meet healthier and more sustainable food systems.

As regards public health perspectives, to reach sustainable development goals at Horizon 2050, public information and sensitization to UPFs should be reinforced while reducing or suppressing "addictive" UPF-related advertising for children, developing a strong holistic education on global health from schools to universities, offering more local and sustainable programs for minimally processed plant-based food consumption, and taxing UPFs. A future research direction may be to quantify the potential environmental

benefit of reducing in the diet animal and UPF calories from 35 to 15%, i.e., at least 20% less, in France.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13137433/s1, Supplementary Tables S1–S3: Median calorie content and percentages (total, plant, and/or animal) of INCA1–3 food categories based on the French Ciqual food database (accessed on 12 March 2021). NB: the percentage of plant and animal calories of mixed/combined INCA food categories are based on most consumed French food dishes (https://www.marmiton.org/ (accessed on 12 March 2021)).

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Conflicts of Interest: Since 2017, Anthony Fardet has been a member of the Siga scientific committee. Edmond Rock, David Thivel, and Laurent Gerbaud declare no conflict of interest.

Abbreviations

DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid; INCA: National Individual Study of Food Consumption; UPFs: ultra-processed foods.

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