

Article

Dietary Imbalance between Natural and Added Nutrient Sources Is Associated with Higher Fat Mass in Young Non-Obese Individuals

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Abstract: Increased energy intake from carbohydrates and sugars has been associated with overweight and obesity, risk factors for type 2 diabetes. However, such an association is higher with westernised diets with higher amounts of processed foods. Our aim was to correlate the dietary intake of sugars and lipids from naturally present and added sources with fat mass in young individuals. We performed an observational study in 80 young non-obese individuals, who completed food frequency and nutritional knowledge (NK) questionnaires, as well as an anthropometric evaluation. Foods were divided into naturally or added sources of sugars and lipids, and the intake from both sources was calculated separately. Individuals with a higher fat mass percentage had lower NK and lower consumption of lipids and sugars from naturally present sources. Moreover, consumption of lipids and sugars from naturally present sources was negatively correlated with nutritional knowledge and anthropometric markers of overweight, especially body weight and waist circumference. In non-obese young adults, lower consumption of sugars and lipids from naturally present sources instead of added ones is higher in individuals with excessive fat mass percentage and correlated with anthropometric markers of fat mass. Such dietary imbalance is associated with lower nutritional knowledge, suggesting that it could be a strategy to strengthen the prevention of obesity and associated pathologies later in life.

Keywords: fat mass; dietary patterns; body composition; lipids; food composition

1. Introduction

Lifestyle changes towards less healthy behaviours with the increased consumption of westernised diets and processed food is associated with the increasing prevalence of overweight in young adults and risk for obesity and associated pathologies later in life. Strategies such as changes in dietary patterns and more nutritional knowledge are necessary to interrupt this cycle, preventing the burden of metabolic syndrome-associated diseases, such as type 2 diabetes, cardiovascular disease, and non-alcoholic fatty liver disease. Dietary imbalance includes the substitution of fish, fruits, and vegetables for fat- and sugar-rich processed foods (soft drinks, snacks/desserts, sweets, fast food, etc.), which are apparently associated with weight gain [1,2].

Previous studies demonstrated the direct proportionality between sugar consumption and development of metabolic disorders, such as obesity and type 2 diabetes, and metabolic syndrome-related pathologies [3–7]. The World Health Organization (WHO) established guidelines for free sugar intake in adults and children below 5–10% of the total daily energy [3]. According to the National Portuguese Food and Physical Activity Survey report, the average national consumption of simple sugars (mono- and di-saccharides) is 90 g (g)/day, contributing to an average of 19.8% for the total energy value and 17.3% in adults [8]. The consumption of free sugars contributes to an increased energy density of the diet, leading to a positive energy balance, higher waist circumference, and weight gain [3,7,9]. Moreover, given the strong association between whole body and abdominal fat mass with type 2 diabetes, cardiovascular diseases, and cancers, the World Health Organization (WHO) guidelines recommend 15–30% of the total daily energy intake from fats and less than 10% intake of saturated fats [10,11]. Fat accumulation and body mass index (BMI) were shown to be directly proportional to the excessive intake of energy in relation to the expenditure, especially from foods rich in fats [10].

Both lipids and sugars may be divided into two distinct groups: those naturally present and those added to foods. Natural or intrinsic sugars are naturally present in foods, such as fruit sugar (fructose), vegetables, honey, and sugars from dairy products (galactose and lactose) [3]. Lipids are naturally present as saturated fatty acids in dairy, egg yolks, chocolate, meats (especially red meat), fish, unsaturated fatty acids in nuts, nonhydrogenated vegetable oils, and seeds [12,13].

The added sugars and lipids include mono- and di-saccharides added to foods during processing, preparation, or at the table, with the objective of sweetening and increasing the food palatability and shelf life, improving the texture, inhibiting growth microorganisms in high concentrations, give functional structures, or give more accessibility [4,7]. Added sugars mainly include yellow sugar, corn sweetener, dextrose, fructose, glucose, high fructose corn syrup, honey, lactose, maltose, malt sugar, molasses, raw, turbinated sugar, trehalose, and sucrose [9]. They are mostly found in sugary drinks, pastry products, cookies, fruit juices, energy drinks, nectars, fruit juices concentrated fruit, white bread, and breakfast cereals [6]. Added lipids are mainly trans fatty acids, such as hydrogenated oils (margarines and shortenings) and saturated fatty acids found in processed foods (such as ham, burgers, prepared sandwiches, and snacks) [14,15].

Anthropometric parameters such as BMI, waist circumference, waist–hip ratio, or fat mass percentage may be useful in the detection of metabolic disturbances long before the development of clinical or biochemical alterations [16]. Waist circumference and waist–hip ratio are apparently better correlated with cardiovascular risk factors, obesity risk, and mortality than weight or BMI, which have several caveats [15,17]. A low level of health literacy, including in the Portuguese population, has been associated with alterations of the anthropometric parameters, namely increased BMI, and is identified as a risk factor for diabetes, cardiovascular disease, and cancer [18]. Low food literacy is associated with poor eating habits, including sugary drink intake and a lower frequency of fruit and vegetable consumption [19].

The aims of this study were to understand the impact of altered food behaviours on several anthropometric parameters recognised as risk factors for obesity and associated pathologies. It was also an aim to correlate the dietary imbalance between naturally present and added lipids and sugars with nutritional knowledge (NK) in order to implement future strategies contributing towards a healthier food behaviour and lifestyle.

2. Materials and Methods

This cross-sectional observational study was performed in non-obese college students from Coimbra Health School and was approved by the Local (removed for blind peer review) Ethics Committee. The participation was voluntary, and the informed and free consent statements were signed. Eighty (62 Women and 28 men) non-obese (median: 21.8; min: 16.3; max: 28.8) young adults aged 18–24 years old were randomly selected and

included in the study. Exclusion criteria were underage, pregnancy, chronic diseases, and presence of pacemakers.

The students were randomly recruited in a voluntary basis and the objectives, requirements, and exclusion criteria were explained to the students before they carried out the questionnaire and anthropometric measurements. The nutritional knowledge questionnaire (NKQ), translated and validated into Portuguese, was applied to analyse the nutritional knowledge of the participants [20]. After self-completion, a score was attributed through the sum of correct answers that indicated the knowledge of the volunteer.

The intake of natural and added sugars and lipids was analysed through a semi-quantitative food frequency questionnaire [20,21], developed and validated for the Portuguese adult population, self-completed by the participants. From the weekly food frequency and registered food portions of each acquired food, the amount of food eaten weekly was obtained using the Ricardo Jorge Institute's food composition table. Foods were divided into three categories: (1) source of added lipids or sugars; (2) natural source of lipids or sugars; (3) mixed source of lipids or sugars. For mixed sources, the total amount of each nutrient was divided by two and included to both the amounts of added and natural sources. Total weekly amount of energy in kilocalories (Kcal), total fat (g), saturated, total unsaturated and monounsaturated fatty acids (g), cholesterol milligram (mg), total carbohydrates (g), and mono- and di-saccharides (g) were calculated for each category.

Regarding the anthropometric evaluation of the participants, the data collected included weight, height, BMI, percentage of fat mass, waist and hip perimeters, as well as hip–waist ratio, which were collected and calculated according to WHO recommendations and the WHO STEPS instrument [22–24]. Height was determined with the aid of a SECA 763 stadiometer. For the measurement of weight, calculation of BMI, and fat mass in kilograms (kg) the electrical bioimpedance INBODY 230 was used. The required conditions that participants must meet to perform a bioimpedance are: individuals should be measured under water and solid fasting in the 4 h prior to the test; should not have taken any stimulating or alcoholic drinks in the last 12 h; should not practice intense or moderate physical activity in the 12 h before the test; individuals must be properly hydrated; volunteers must remove all metallic ornaments, shoes, and socks; they must urinate within 30 min before the test; and should not take diuretics in the 7 days before the test. Perimeter measurements were performed using a tape measure. According to BMI, participants were divided into the categories of low weight ($<18.5 \text{ Kg/m}^2$), normal weight (≥ 18.5 , $<25 \text{ Kg/m}^2$), and excessive weight ($>25 \text{ Kg/m}^2$). According to the waist–hip ratio, participants were divided into the categories of low risk (<0.71 in women and <0.83 in men), moderate risk (≥ 0.71 and <0.77 in women and >0.83 and <0.87 in men), and high or very high risk (≥ 0.78 in women and ≥ 0.88 in men). Based on the fat mass percentage, the participants were divided into the categories low or normal fat ($<28\%$ in women and $<24\%$ in men) and excessive fat or obese ($\geq 28\%$ in women and $\geq 24\%$ in men) [22–24].

Anthropometric and nutritional data were analysed with the IBM SPSS Statistics Version 26 software, using nonparametric correlations with Spearman's correlation coefficients and the Kruskal–Wallis for multiple comparisons. Data normality was assessed through the Kolmogorov–Smirnov test. A *p*-value lower than 0.05 was considered statistically significant.

3. Results

The participants included in the “Fat or Obese” group (higher fat mass) showed a lower consumption of fat ($p < 0.05$), saturated fatty acids ($p < 0.05$), monounsaturated fatty acids ($p < 0.06$), and unsaturated fatty acids ($p < 0.1$) from naturally present sources (Figure 1). No differences were observed in energy, carbohydrates, and sugars from naturally present sources (Figure S1) nor in any nutrient class from added sources (Figure 1). Interestingly, such individuals, although with higher fat mass, consumed lower total levels of fat ($p < 0.05$), saturated fatty acids ($p < 0.05$), monounsaturated fatty acids ($p < 0.05$), and unsaturated fatty acids ($p < 0.09$) due to their lower consumption from naturally present sources (Figure 1).

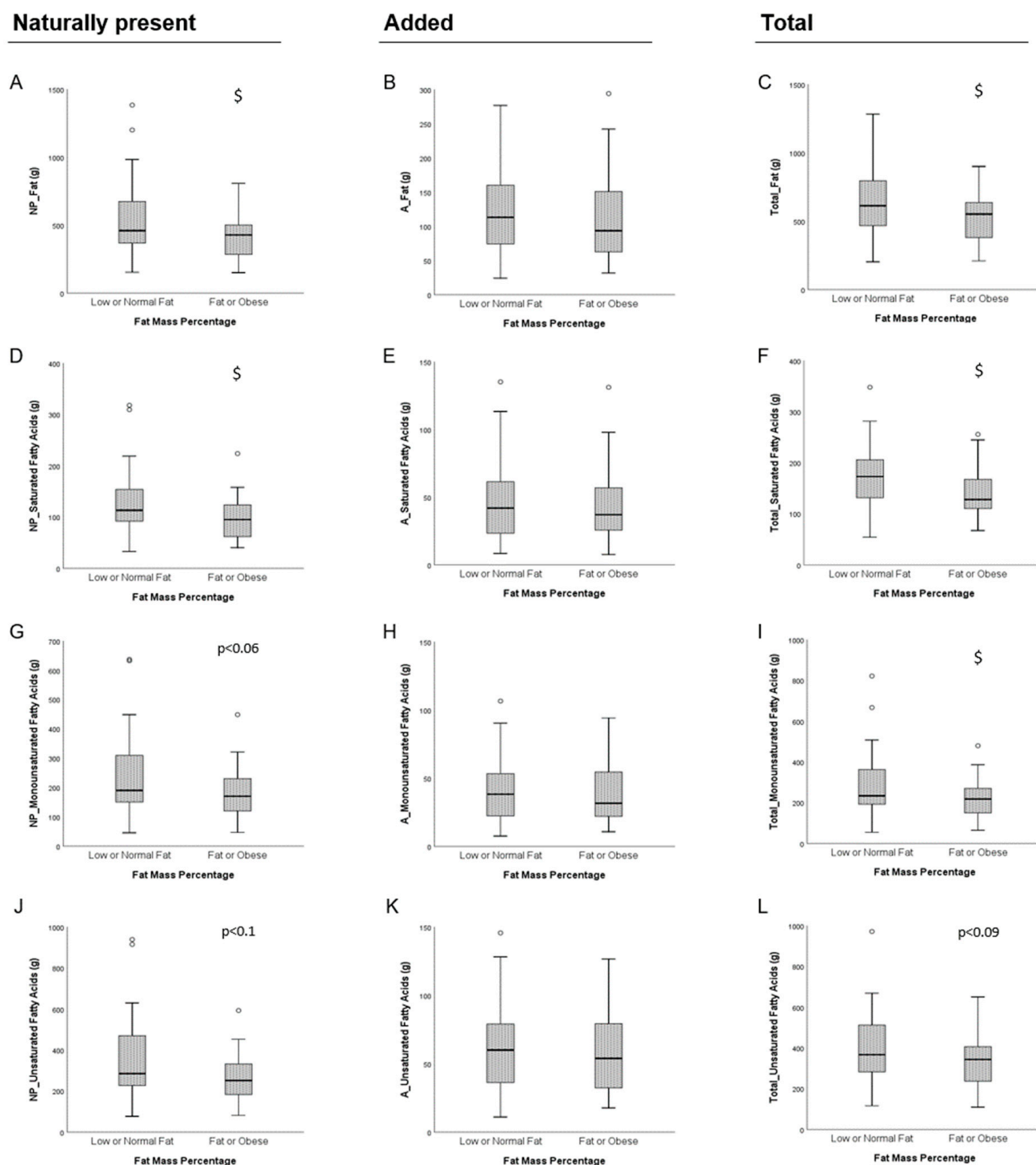


Figure 1. Distribution of fat consumption in individuals with low or normal fat mass and individuals with a higher fat mass percentage, defined accordingly to established cut-off points. The data show weekly consumption of fat (A–C), saturated fatty acids (D–F), monounsaturated fatty acids (G–I), and unsaturated fatty acids (J–L), from naturally present (left column) or added sources (central column), as well as the total weekly consumption (right column). \$ shows significant differences between groups, $p < 0.05$. ° (outliers, SPSS layout).

The participants included in the “Fat or Obese” group also showed a lower NKQ score ($p < 0.001$) (data not shown), and similar results of nutrient sources were obtained when using NK for comparison. Remarkably, participants with the NKQ score above the median consumed more energy ($p < 0.05$), fat ($p < 0.01$), unsaturated fatty acids ($p < 0.001$), carbohydrates ($p < 0.05$), and mono- and di-saccharides ($p < 0.001$) from naturally present

sources (Figures 2 and 3). They also consumed more cholesterol ($p < 0.01$) from added sources (Figure 3H). Thus, lower total consumption of fat ($p < 0.01$), unsaturated fatty acids ($p < 0.01$), and mono- and di-saccharides ($p < 0.01$) in individuals with lower NK may be attributed to their lower intake from naturally present sources (Figures 2 and 3).

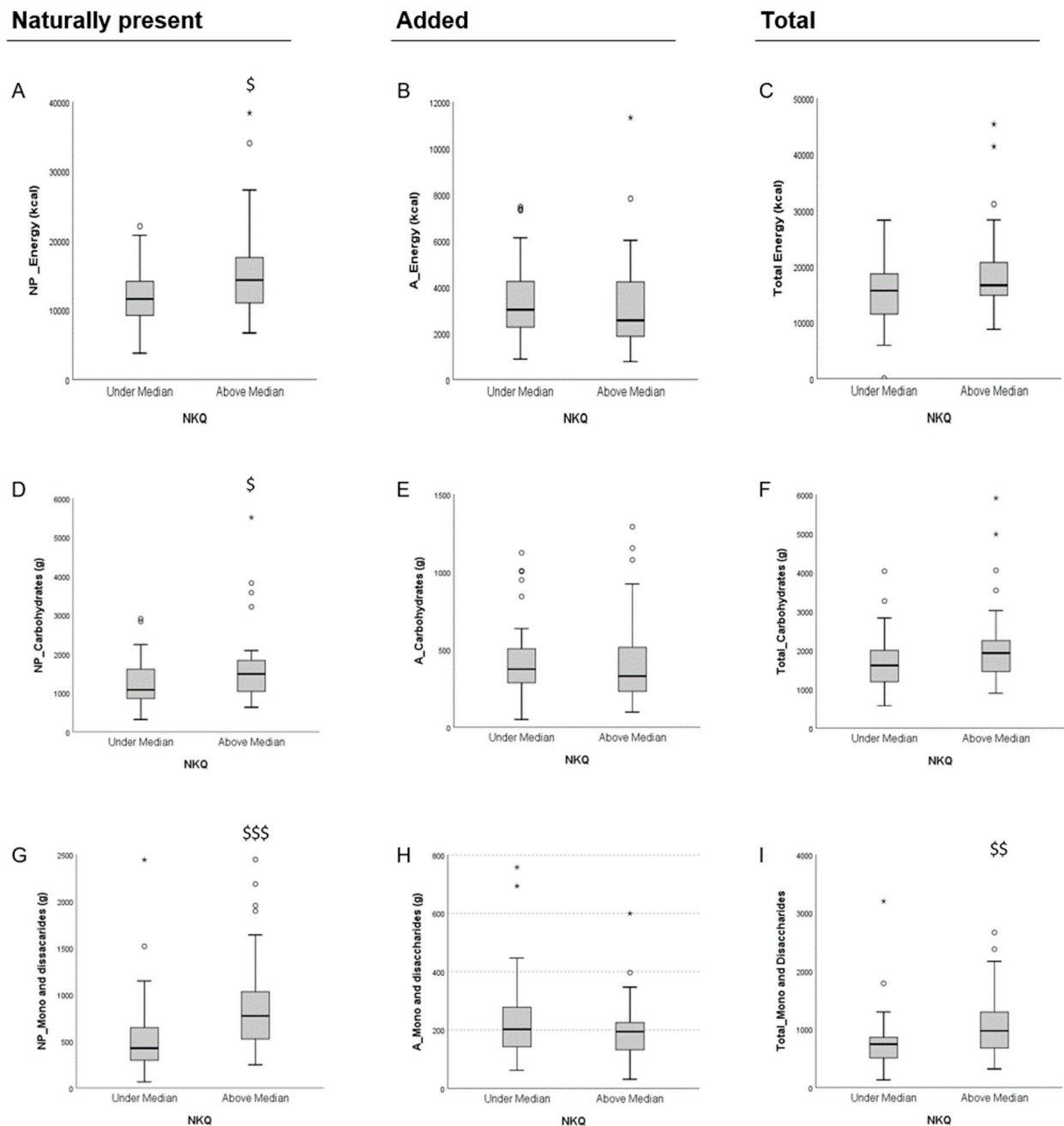


Figure 2. Distribution of energy and carbohydrates consumption in individuals with nutritional knowledge under and above median. The data show weekly consumption of energy (A–C), carbohydrates (D–F), and mono- and di-saccharides (G–I) from naturally present (left column) or added sources (central column), as well as the total weekly consumption (right column). \$ shows significant differences between groups, \$ $p < 0.05$, \$\$\$\$ $p < 0.01$, \$\$\$\$ $p < 0.001$. * or ° (outliers, SPSS layout).

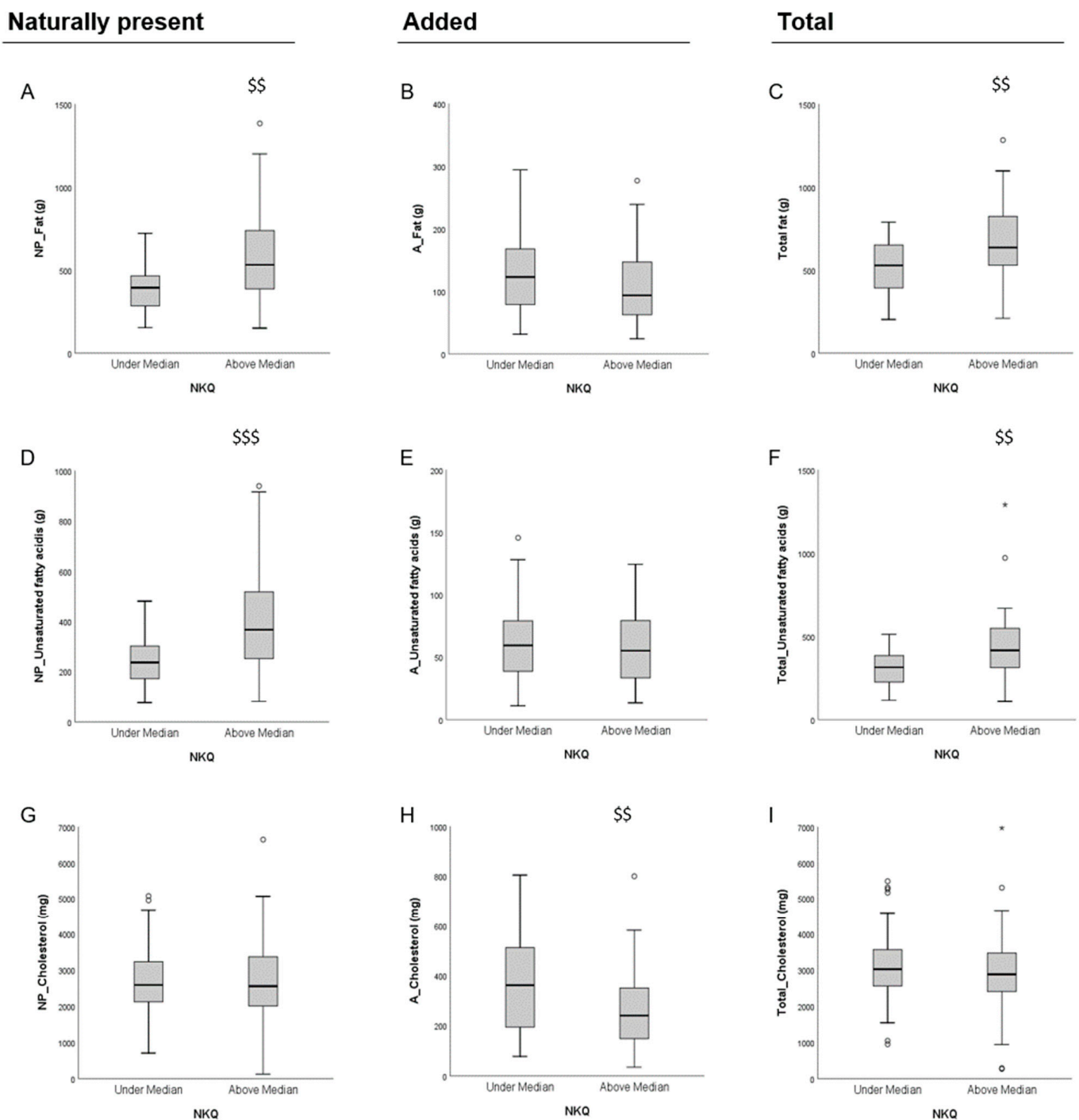


Figure 3. Distribution of fat consumption in individuals with nutritional knowledge under and above median. The data show weekly consumption of fat (A–C), unsaturated fatty acids (D–F), and cholesterol (G–I) from naturally present (left column) or added sources (central column), as well as the total weekly consumption (right column). \$ shows significant differences between groups, \$\$ $p < 0.01$; \$\$\$ $p < 0.001$. * or ° (outliers, SPSS layout).

In fact, nutritional knowledge (NK) was positively correlated with the consumption of lipids and sugars from natural sources (Table 1). Moreover, Table 2 shows an inverse correlation between the NKQ score and waist circumference, suggesting that lower NK is associated with higher levels of abdominal fat in non-obese young individuals. No differences were observed between the BMI and waist-hip ratio categories regarding NK.

Table 1. Summary of the Spearman correlation analysis between the nutritional knowledge questionnaire score and the sources of dietary lipids and sugars ($n = 81$).

	NKQ	
	<i>p</i>	<i>p</i> Value
Naturally present sources		
NP_Energy (Kcal)	0.278	0.013
NP_Fat (g)	0.359	0.001
NP_MUFA (g)	0.456	<0.001
NP_Uns FA (g)	0.405	<0.001
NP_Sat FA (g)		
NP_Cholesterol (g)		
NP_Carbohydrates (g)	0.256	0.023
NP_Mono/Disaccharides (g)	0.385	<0.001
Added sources		
A_Energy (Kcal)		
A_Fat (g)		
A_MUFA (g)		
A_Uns FA (g)		
A_Sat FA (g)		
A_Cholesterol (g)	−0.274	0.014
A_Carbohydrates (g)		
A_Mono/Disaccharides (g)		
Total		
Total_Energy (Kcal)		
Total_Fat (g)	0.324	0.004
Total_MUFA (g)	0.428	<0.001
Total_Uns FA (g)	0.386	<0.001
Total_Sat FA (g)		
Total_Cholesterol (g)		
Total_Carbohydrates (g)		
Total_Mono/Disacch. (g)	0.298	0.008

In all of the population studied, body weight was negatively correlated with energy, fat, saturated fatty acids, unsaturated fatty acids, monounsaturated fatty acids, and mono- and di-saccharides obtained from naturally present sources (Table 2). Such results were also observed for total fat, unsaturated fatty acids, and monounsaturated fatty acids, but not for any nutrient from added sources. Similar results were also observed for BMI, being negatively correlated with fat, saturated fatty acids, unsaturated fatty acids, and monounsaturated fatty acids obtained from naturally present sources (Table 2). BMI was also negatively correlated with total consumption of fat, saturated fatty acids, unsaturated fatty acids, monounsaturated fatty acids, and mono- and di-saccharides, but not from added sources. Regarding fat mass percentage, only a negative correlation with the consumption of saturated fatty acids from naturally present sources was observed (Table 2).

Waist circumference was negatively correlated with energy and the consumption of fat, unsaturated fatty acids, monounsaturated fatty acids, and mono- and di-saccharides obtained from naturally present sources (Table 2). Waist circumference was also negatively correlated with total consumption of fat, unsaturated fatty acids, and monounsaturated fatty acids (Table 2). Hip circumference was, as well, negatively correlated with the consumption of fat, monounsaturated fatty acids, and saturated fatty acids obtained from naturally present sources and their total consumption. Waist-hip ratio was negatively correlated with the mono- and di-saccharides obtained from naturally present sources (Table S1). No correlations were obtained between the consumption of such nutrients obtained from added sources and none of the anthropometric parameters. Only cholesterol consumption from added sources was positively correlated with waist-hip ratio (Table S1).

Such results suggest that fat mass measures are correlated with the lower consumption of naturally present sugars and lipids and such a decrease contributes more to higher fat mass than alterations in the total amount of energy intake, as well as the total consumption of lipids and sugars.

Table 2. Summary of the Spearman correlation analysis between weight, body mass index, and fat mass percentage with the sources of dietary lipids and sugars ($n = 81$).

	Weight (Kg)		BMI (Kg/m ²)		Waist (cm)		Fat Mass (%)	
	<i>p</i>	<i>p</i> Value	<i>p</i>	<i>p</i> Value	<i>p</i>	<i>p</i> Value	<i>p</i>	<i>p</i> Value
Naturally present sources								
NKQ					−0.240	0.033		
NP_Energy (Kcal)	−0.257	0.022			−0.235	0.037		
NP_Fat (g)	−0.378	0.001	−0.264	0.019	−0.237	0.036		
NP_MUFA (g)	−0.386	0.001	−0.247	0.012	−0.260	0.021		
NP_Uns FA (g)	−0.377	0.001	−0.229	0.042	−0.240	0.033		
NP_Sat FA (g)	−0.284	0.011	−0.282	0.012			−0.282	0.012
NP_Cholesterol (g)								
NP_Carbohydrates (g)								
NP_Mono/Disacch. (g)	−0.234	0.038			−0.246	0.029		
Added sources								
A_Energy (Kcal)								
A_Fat (g)								
A_MUFA (g)								
A_Uns FA (g)								
A_Sat FA (g)								
A_Cholesterol (g)								
A_Carbohydrates (g)								
A_Mono/Disacch. (g)								
Total								
Total_Energy (Kcal)								
Total_Fat (g)	−0.332	0.003	−0.284	0.011	−0.225	0.046		
Total_MUFA (g)	−0.353	0.001	−0.249	0.027	−0.239	0.034		
Total_Uns FA (g)	−0.355	0.001	−0.236	0.036	−0.238	0.035		
Total_Sat FA (g)			−0.253	0.024				
Total_Cholesterol (g)								
Total_Carbohydrates (g)								
Total_Mono/Disacch. (g)								

4. Discussion

In this study, we observed that the lower consumption of sugars and lipids from naturally present sources instead of added ones is associated with a higher fat mass percentage and correlated with anthropometric markers of overweight, namely body weight and waist circumference of non-obese young adults. Moreover, such dietary imbalance is mostly observed in individuals with lower nutritional knowledge. Such observations may have strong impacts on the risk of developing type 2 diabetes later in life and the development of preventative measures.

The relevance of nutritional knowledge for the modulation of dietary patterns has been demonstrated in several studies. Young adults with higher nutritional knowledge have been shown to be aware of the relevance of consuming healthier foods, namely white meat, vegetables (dark green and orange), soup, whole fruit, complex carbohydrates, and dietary fibre, but lower total and saturated fat, cholesterol, canned fruit, and juice/soda drinks [25–27]. Moreover, increasing health literacy was shown to be effective in improving eating behaviours, namely increased consumption of fruits and vegetables [28]. Health literacy was also strongly associated with the Healthy Eating Index and consumption of

sugar-sweetened beverages [19]. Lower nutritional knowledge was previously associated with higher BMI, and the improvement of health habits through nutritional education programmes was shown to reduce body weight/BMI [29,30]. In our study, we observed lower nutritional knowledge in individuals with higher fat mass and a negative correlation with waist circumference. Visceral fat was observed to strongly correlate with waist circumference and waist–hip ratio, which, together with our results, suggest that the reduction of abdominal fat in young non-obese populations may be mostly accomplished by the implementation of better nutritional education programmes at college and university [31].

Although nutritional knowledge is correlated with increased consumption of natural non-processed foods instead of processed ones, there is still a substantial debate whether the macronutrient proportion, the energy density, or the source of nutrients are the main determinants for adiposity and metabolic syndrome. Although some past studies have observed weight reduction after lower consumption of fat intake, such an effect was not consistently observed in cohort studies addressing the relationship between total fat intake and measures of adiposity in all ages (children, young people, or adults) [32]. Changes of dietary habits to primary intake of energy as carbohydrate or fat did not significantly change visceral fat after three months, suggesting that dietary fat amount is not a factor that determines fat mass per se [10]. Similar observations were made by Lee et al. (2010), where no correlations were observed between macronutrient intake and anthropometric measures of fat mass, although higher energy intake was weakly correlated with BMI and waist circumference [33]. Thus, total levels of macronutrient intake are not apparently a determinant of overweight or obesity in non-obese individuals. In our study, the total energy intake was not correlated with any anthropometric measure, and all of the correlations between total nutrient intake and anthropometric parameters were mainly determined by the consumption from naturally present sources, reinforcing the idea that total macronutrient intake is not a determinant of fat mass markers, at least in non-obese populations.

The consumption of unprocessed natural foods has been suggested as a protective dietary strategy to improve metabolic syndrome components and biochemical markers of disease [34,35]. On the other hand, the consumption of processed foods with higher sugar and fat content has been suggested as a risk factor for the development of metabolic syndrome components [34]. The consumption of fast food has been considered in many observational studies as a risk factor for being overweight or obese in both developed and developing regions, even after controlling for energy intake [36]. Although there is a variability of dietary classifications between studies, consumption of ultra-processed foods has been consistently shown to be associated with body fat during childhood and adolescence [37,38]. Similar results were found by Juul et al. (2018), namely a strong relation between the consumption of ultra-processed foods and BMI or waist circumference [37]. Such evidence suggests a relation between fat mass and increased consumption of nutrients of added sources, even after controlling for energy intake. Indeed, meta-analyses have concluded a positive association between the intake of sugary drinks and the risk of higher fat mass and obesity [39]. Higher intake of sugar-sweetened drinks was associated with poorer dietary choices and correlated with higher BMI and waist circumference in children [38]. In fact, a recent study by Fox and colleagues (2021) has shown an increase in children's sugar intake from added sources in school breakfasts and lunches [40]. About 63% of children were shown to surpass the added sugars intake limit defined by the Dietary Guidelines for Americans for 24 h [40]. In adults, an increased daily dietary glycaemic index was positively associated with higher BMI, again with little effect of the percentage of calories from carbohydrates or total carbohydrate consumption [41]. In our study, we observed that increased fat mass was associated with lower consumption of fats and sugars from naturally present sources, with the highest impact being observed in abdominal fat. Individuals with higher fat mass showed lower consumption from naturally present sources, and the strongest correlations were observed for weight and waist circumference. Although weaker correlations were observed for BMI and waist–hip ratio, this may be a

consequence of the population studied. Most of the studies include obese individuals in the search for correlations between dietary habits and fat mass markers. Here, we did not include individuals with obesity in order to identify dietary patterns and correlations with fat mass markers prior to obesity. In our study, no significant differences were observed for the waist–height ratio (data not shown). Waist–height ratio was recently described as the better predictor of body fat mass [11]. In this study, the authors established cut-off points for obesity based on waist–height ratio (0.53 in men and 0.54 in women), but in our study none of the participants surpassed such values. Thus, waist–height ratio may be weaker in discriminating body fat mass in non-obese populations.

Most of the previous studies have determined the type of food consumed by the participants and correlated the type of nutrient with the anthropometric data. Here, we calculated the weekly amount of each nutrient consumed from naturally present and added sources. Our study has some limitations, such as the lower sample size than that of other studies, volunteers were recruited only in one site, and it is a cross-sectional study, with more longitudinal studies necessary in the future. Nevertheless, our data suggest that alterations of the dietary habits with increased consumption of sugars and fats from natural sources and less from ultra-processed foods may have a significant impact in reducing the overweight risk among young populations. Such changes of dietary habits may have a huge public health impact in prevention of obesity and related pathologies. The available data reinforce the need of better nutritional knowledge since childhood to achieve sustained lifestyle changes and better dietary habits. Better nutritional knowledge and alterations of the dietary habits with increased consumption of sugars and fats from natural sources and less from ultra-processed foods may be an important strategy in reducing adiposity among young populations, as well as a huge public health impact in the prevention of obesity and related pathologies throughout life, such as type 2 diabetes. Another point to improve is having better physical activity facilities in schools and universities, with easy and affordable access for the students, as well as physical activity promotion programmes.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/diabetology2020008/s1>, Figure S1: Distribution of energy and carbohydrates consumption in individuals with low or normal fat mass and individuals with higher fat mass percentage, defined accordingly to established cut-off points. Data shown weekly consumption of energy (A, B, C), carbohydrates (D, E, F) and mono and disaccharides fatty acids (G, H, I) from naturally present (left column) or added sources (central column), as well as the total weekly consumption (right column). Table S1: Summary of the Spearman correlation analysis between Hip Circumference and Waist/Hip Ratio with the sources of dietary lipids and sugars.

Author Contributions: M.S.-M. and M.M. were responsible for data collection and analysis. J.F. was responsible for statistical analysis. A.F., H.L., and S.F. were responsible for questionnaire preparation and data collection and analysis. P.M. is the guarantor of the work and data and was involved in experimental design, data analysis, and was responsible for manuscript preparation. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the (or Ethics Committee) of Coimbra Health School (protocol code 8/2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be available upon reasonable request to the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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