Metal Ions in Life Sciences

Dietary Sources of Macronutrient Intake and Nutritional Adequacy in Children with Cystic Fibrosis: A European Multicenter Nutritional Epidemiology Study

Dr. Amina El-Sayed[1]*

Dr. Sofia Marinova[2]

Prof. Henrik Larsen[3]

[1] University of Copenhagen, Department of Pediatric Nutrition and Clinical Metabolism, Copenhagen, Denmark

[2] Medical University of Warsaw, Institute of Clinical Dietetics and Pediatric Gastroenterology, Warsaw, Poland

[3] University of Oslo, Department of Public Health Nutrition and Chronic Disease Epidemiology, Oslo, Norway

ABSTRACT

Background: Optimal nutrition for children with cystic fibrosis (CF) improves prognosis and survival, but an increased caloric intake recommendation for this population raises concerns about the nutrient profile of their diets.

Objective: To assess the relative contribution of food groups to the total macronutrient intake by European pediatric CF patients.

Design: Cross-sectional study in which the participants recorded dietary intake from 2016 to 2017. Specifically developed nutritional composition databases were used to obtain nutritional data, including macronutrients and food groups, according to previously standardized criteria.

Participants/setting: Two hundred seven pediatric patients with CF from six European centers were involved in the My App for Cystic Fibrosis (MyCyFAPP) self-management project.

Main outcome measures: Participants reported dietary intake with a detailed four-day food record.

Statistical analysis performed: Descriptive analyses on nutrient intake, food group consumption, and dietary origin of macronutrients were conducted with R software.

Results: Similar patterns were found in nutrient and food group intake; both sugar and saturated fatty acids contributed >10% each to the total daily energy intake in all the centers. Large mean and median percent differences were observed in the intake of other nutrient and food groups, because sweets and snacks were consumed once or twice a day, and fruit and vegetables were consumed two or three times a day. Milk, meat, sweets and snacks, and oils were the main sources of fat in all centers.

Conclusions: Study findings indicated less than optimal nutrient profiles, especially for sugars and saturated fatty acids, resulting from the high consumption of meat, dairy, and processed products and low consumption of fish, nuts, and legumes. These results can serve as a basis for future tailored interventions that target improved adherence to nutritional recommendations for CF patients.

INTRODUCTION

Children with cystic fibrosis (CF) have a high nutritional risk for several reasons. Pancreatic insufficiency is present in 80–90% of CF patients [1,2]. If not adequately corrected, this insufficiency results in nutrient maldigestion, which leads to malabsorption [3] and a negative impact on nutritional status. This, in addition to the increased energy requirement and possible lack of appetite that compromises intake, results in a less than optimal nutrient intake and compromises nutritional status [1]. Prevention and treatment of malnutrition are of major importance, because an optimal nutritional status improves overall prognosis and survival [3,4].

Nutritional intervention in CF patients consists of dietary recommendations of energy intake and macronutrient distribution, fat-soluble vitamin supplementation, and life-long pancreatic enzyme replacement therapy (PERT). In this respect, the current "European Guidelines on Nutrition in CF" has recently updated the nutritional goals and dietary recommendations to be achieved by CF patients [5].

These guidelines advise the *ad libitum* consumption of high-fat foods when weight gain is necessary. In this case, the energy intake should be as wide as 110% to 200% of the recommended intake for the healthy population, distributed as 40% fat, 40% carbohydrates, and 20% protein. Concerns of increased saturated fats in the diet related to this recommendation are acknowledged in the guidelines [5]. With the remarkable improvement in survival, patients with CF may be at risk for cardiovascular disease, obesity [6,7], and other age-related conditions associated with the high consumption of saturated fatty acids and sugar. According to the World Health Organization (WHO), the intake of saturated fatty acids should be less than 10% [8] and the intake of sugar should not exceed 5% of total daily energy intake [9]. Therefore, having a balanced and healthy diet will become of utmost importance, and fats with unsaturated fatty acids are recommended as the predominant fat source [5].

Moreover, a recent systematic review that focused on the historical perspective of dietary intake studies in children with CF (1969–2016), shows that “the nutrition dogma has to be extended from nutrition for growth and survival to nutrition for health and well-being” [10]. All the studies that were evaluated took energy intake into consideration. Among them, about 33–66% looked at macronutrient intake and only 3% included food group variety. Fewer than 50% of the studies used 24-hour dietary recalls to obtain information about foods and beverages consumed. Authors claimed a need to generate contemporary information in dietary intake in the CF population [10].

One of the main objectives of the MyCyFAPP project [11] was to empower CF patients’ self-management to achieve an optimal nutritional intake. Thus, in the first stage of the project, the nutritional status, actual PERT dose, and macronutrient intake of a cohort of pediatric CF patients from six European countries were compared with respect to the new guidelines on nutrition in CF [12]. Poor compliance with the recent recommendations as well as large differences in compliance across centers were observed. Patients had low protein consumption, high consumption of carbohydrates and low total fat intake [12]. In order to more closely meet dietary recommendations in this population, the assessment of dietary intake and calculation of nutrient profiles may facilitate tailored interventions related to food selection.

Therefore, the aim of the present study was to describe nutrient intake in relation to food group consumption by children with CF to assess the relative contribution of each food group to total macronutrient intake.

MATERIALS AND METHODS

Subjects and study design

A multicenter, cross-sectional, observational study was carried out with 210 CF patients, ranging in age from two to 17 years old, in regular follow-up at six European CF centers: Lisbon, Portugal (30 patients); Madrid, Spain (33 patients); Valencia, Spain (36 patients); Milan, Italy (30 patients); Leuven, Belgium (29 patients); and Rotterdam, the Netherlands (52 patients). Three patients dropped out of the study. Partial results of this study have been previously published [12].

Inclusion criteria required a confirmed diagnosis of CF at least six months prior and age between two and 18 years old. Patients who had undergone organ transplantation were excluded. Pancreatic sufficiency was not an exclusion criterion.

The study protocol was approved by the ethical committees of each participating center, as a sub-study within the MyCyFAPP project (Horizon 2020, 643807), and conducted according to the Declaration of Helsinki guidelines. All parents and patients >12 years old gave written, informed consent.

Nutritional data collection and processing

A specifically developed 4-day food record was used for two reasons: first, no standard form was internationally indicated and, second, the study required a very concrete structure, including instructions and examples for participants to follow when filling the record out. All meals were registered in terms of "name of the meal," "ingredients," and "amounts" of food. Patients were provided with written instructions, including a household-measure equivalence table to support estimation of the amount of foods. Dietitians were responsible for training the patients and their families on how to fill in the food records according to a common consensus criterion among the centers. The methods used are described in detail in the first published paper of the MyCyFAPP project [12].

The nutritional composition databases used for the energy and nutrient intake calculation were purchased from EuroFIR® (Spain [13], Portugal [14], Italy [15], and Netherlands [16]), and Nubel® [17] (Belgium), because they were country-specific and contained the nutritional facts of the particular food products in each region. Calculations were automatically performed by the system through the specifically developed calculation tools of the project. The nutrients that were present in the majority of food items were evaluated: energy, protein, total carbohydrates (CH), sugar (including all types of mono and disaccharides), fat, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), fiber, calcium (Ca), iron (Fe), and sodium (Na). Information on the nutrient composition sources did not specify the extent to which the "sugar" item referred to natural sugar of foods or to "free sugar" [13-17] as defined by Fidler Mis et al. (2017) [18]. For most of the food products, missing nutrient data for sugar, SFA, MUFA, PUFA, Ca, Fe, and Na in foods were completed by consulting the labeling of specific brands and other official nutritional composition databases. Information on other minerals and vitamins was minimal in the consulted sources and, thus, were not considered.

In addition, food items were assigned to a food product category or group. After consulting a number of nutritional guidelines and reports from recognized health authorities [19-21] and the classification established by the national official nutritional composition databases [13-17], a total of 13 groups were established: milk and dairy, meat, fish, eggs, fruit, vegetables, legumes, starchy products and grain, sweets and snacks, beverages (excluding water, because it does not contain the assessed nutrients), oils, solid fats, and nuts (**Table 1**). Consensus on the classification criteria was achieved among the registered dietitians involved.

Calculations and statistical analyses

For energy and nutrient intake calculations, data were grouped per patient. The estimated mean total daily intake for each patient was calculated by summing the four days of total intake of energy (in kilocalories [kcal]) and the four days of intake for each nutrient (in grams [g] or milligrams [mg]) and dividing by 4. Values of total daily energy intake were reported as kcal/day and kcal/kg/day. For macronutrients, g/day and g/kg/day units were used, whereas micronutrients were expressed as mg/day and mg/kg/day units. The macronutrient intake was also expressed in percentage as the daily contribution of each specific macronutrient (kcal/day) to the total daily energy intake (kcal/day).

The distributions for food, nutrient and energy intake were not normally distributed. Consequently, to assess overall differences in energy intake among centers, quantile regression analysis was performed to compare two nested models. One model included the independent variables center, age, and sex, and the second model included only age and sex. A mixed-effects quantile regression was performed with center as a random intercept to estimate the effects of age and sex while accounting for correlation among patients within the center.

Estimated frequency of consumption of food groups was calculated by adding the total number of times a food group was consumed by each patient and dividing by four (the number of recording days). The portion size consumed of each food group by the patient was estimated by summing the amount in grams for each food group and dividing by the number of times consumed. The median per center was then identified.

Daily intake, classified by each food group for each patient, was calculated by adding the values for all four days and then dividing by four recording days to obtain the macro- and micronutrient details of the estimated average consumption per food group.

To identify the contribution of each food group to the daily energy intake for macronutrients, the contribution of each person was calculated as a percentage. Daily kilocalories of each food group was divided by total daily kilocalories of the macronutrient. Then the median percentage from each food group for each macronutrient per day was identified. Only food groups with the highest median percent contribution to each macronutrient intake were reported in the results section.

The data were exhibited in the tables as medians with the first and third quartile values. To assess variability, the median absolute deviation was calculated for the nutrients and for energy intake. The median absolute deviation is a robust, alternative measure of statistical dispersion such as the variance and standard deviation (SD) for normally distributed data. The 95% confidence intervals (95% CI) were generated using the bias-corrected and accelerated (BCa) bootstrap interval method with 1000 replicates. Statistical descriptive analyses were performed using R 3.5.1 and clickR (version 0.4.04), Quantile Regression (quantreg) (version 5.35), Regression Modeling Strategies (rms) (version 5.1-2), and Linear Quantile Mixed Methods (lqmm) (version 1.5.4) packages [22].

RESULTS

A total of 828 dietary records, listing 4554 meals, were obtained from 207 children with CF. The participants reported a median number of five meals (including main meals and snacks) per day. Demographic and clinical characteristics of the study population **(Table 2)** were partially reported before by Calvo-Lerma et al. (2017) [12]. Only four subjects from Leuven were receiving enteral or parenteral nutrition support.

Energy and nutrient intake among countries

Table 3 shows the median daily intake of energy, macro- and micronutrients, and the relative contribution of macronutrients to the total energy intake by children with CF in six European centers. There were, overall, statistically significant differences in energy intake between the centers (p

<0.001), adjusted by age and sex. Older ages and male sex were associated with higher median energy intake. As age increases by one year, the daily energy intake increases 82.3 kcal (95% CI [58.2, 106.4], $p < 0.001$). As for male sex, there was also a statistically significant positive effect $\beta = 175.4$ kcal, (CI [13.9, 336.9], $p = 0.03$) regarding the median daily energy intake compared to female sex.

Median total sugar intake was higher than 10% of the total energy intake in all the centers, with median intakes, ranging from 10.8% to 27.5%. SFA and MUFA represented the highest contribution to the total fat intake in all the centers, both with median intakes around 40%. PUFA showed the lowest contribution, with large differences between the centers, with median intakes ranging from 9.3% to 17.6%. Dietary fiber also showed a wide spectrum of consumption, from a median of 10.5 to 17.0 g/day. Intake of Ca and Na varied between centers. Na intake reflected dietary sources only and excluded any contribution from electrolyte solution supplements. Dietary Fe intake was more evenly distributed among centers.

Frequency of consumption of food groups between centers

Table 4 shows the median frequency of consumption of food groups expressed in number of times consumed per day in different centers. Milk and dairy products group had the highest median frequency of consumption in all the centers (3 to 4 times/day), followed by starchy products (around 3 times/day). Meats were consumed a median of 1-2 times/day, whereas fish and eggs were consumed less than once a day. In general, vegetables were consumed more than fruits in all the centers. The median consumption of sweets and snacks was found to be one to two times/day. Oils were mainly consumed in Madrid, Valencia, and Milan, whereas solid fats had a similar frequency of consumption in Leuven and Rotterdam, and Lisbon had a similar consumption of both types of fat. Legumes and nuts groups had the lowest median consumption in all centers. Beverages, excluding water, showed a wide spectrum of consumption (0.4 to 3.4 times/day).

Dietary origin of nutrients

Proteins

Meat products and milk and dairy were the major sources with the highest median percent of contribution to protein intake (kcal/day) in all the centers, as shown in **Figure 1**. In Lisbon, Valencia, Leuven, and Madrid, meat was the first source, and in Milan, meat and milk and dairy made very similar contributions, whereas in Rotterdam milk and dairy, starchy products, and meat products all contributed similarly.

Most of the centers had the third source of protein in common, represented by starchy products (except in Rotterdam, where it was meat). However, two alternative patterns were observed in the fourth group contributing to the total protein intake. In Lisbon, Valencia, and Madrid, intake included fish products but in Leuven, Rotterdam, and Milan intake included sweets and snacks. Eggs and nuts had minimal median percentage of contribution to the protein intake in all centers.

Carbohydrates

All centers had starchy products as the main source of carbohydrates (see **Figure 2**). Sweets and snacks were the second source of carbohydrates and milk and dairy the third in most of the centers, but in Madrid, the median consumption of milk and dairy was higher than the median consumption of sweets and snacks.

The median percent contribution of fruit to carbohydrate intake was approximately twice the contribution of vegetables intake in all centers. Legumes had a negligible role on energy intake in all the centers.

Sweeteners (sugar, honey, and other sugar-based products) also provided a variable contribution in all the centers, higher in Valencia, Madrid, Rotterdam, and Leuven than in the other centers. Regarding the sugar-type carbohydrates, starchy products had a minor contribution to sugar, whereas milk and dairy, sweets and snacks, and fruit and sweeteners were the main sources of sugar.

Fat

The dietary sources of fat intake showed different median percentages among centers (**Figure 3**). In Lisbon and Valencia, meat fat had the highest median percentages for total fat intake (medians = 27.0% and 26.0%, respectively), and milk and dairy products were the second source of fat. In the rest of the centers, milk and dairy was the first source of fat. The second source was oils, in Madrid and Milan, and sweets and snacks in Leuven and Rotterdam. In all these centers, meat was the third source of fat, except in Milan. In Valencia, Madrid, and Milan, the fat from oils contributed more than solid fats to the total intake of fat, whereas in Lisbon, Leuven, and Rotterdam, this tendency was in reverse order.

Across all centers, the median percent contribution (kcal/day) of meat products to SFA and MUFA intake was similar as was the median percent contribution for sweets and snacks. The milk and dairy group had the highest median percent contribution to SFA intake in all the centers, ranging from 10.8% in Lisbon to 19.3% in Milan. MUFA were provided mainly by oils in Madrid, Valencia, and Milan, whereas the main sources of MUFA were meats and sweets and snacks in Lisbon, Leuven, and Rotterdam. Finally, the highest PUFA intake was associated with meat, sweets and snacks, and starchy products in all the centers, but overall, its intake was evenly distributed among all the food groups. Neither nuts nor fish contributed to the total fat or PUFA intake.

The overall contribution of food groups to macronutrient intake by the entire study population is summarized in **Figure 4;** the food groups contributing the most to fat and protein intake were milk and meat (20.3% and 17.6%, respectively for fat, and 22.9% and 30.9%, respectively, for protein), whereas starchy products and sweets and snacks were the main contributors to carbohydrate consumption (36.8% and 18.4%, respectively).

4. DISCUSSION

In this European study, a detailed assessment of food group intake, macro- and micronutrient intake, and dietary origin of the macronutrients according to food group, was carried out among children with CF. The main findings in relation to nutrient intake were: first, a high intake of SFA [8] with low

PUFA and MUFA and, second, high sugar consumption [9] in all the centers. Moreover, considerable differences in sources of protein and fat were found between the centers.

Results also revealed low consumption of fruit, vegetables, legumes, eggs, and fish. On the other hand, sweets and snacks were overconsumed. These results agree with previous reports from studies in the general pediatric population over the past two decades; Brown et al. (1998) [23] concluded that processed products and fast-food style meals were prevalent in the general young population, and Braithwaite et al. (2017) [24] reached the same conclusion in their multi-country study of children and adolescents. More specifically, in recent studies conducted among healthy children of the countries included in the present study, similar findings were obtained [25-29]. This suggests that nutritional habits in children with CF do not differ from those belonging to the general population. Nevertheless, a recent study showed that children with CF are achieving a higher energy intake than the general population, by frequent consumption of "energy-dense, nutrient-poor" foods [30]. However, to the best of our knowledge, no study is available specifically focusing on food group intake in CF populations in the literature. Therefore, the current study is one of the first studies to widely address both nutrient and food intake by children with CF from different European countries.

Presenting data on how food groups and nutrient composition interrelate provides novel insights into the diets of children with CF. For example, patients from Lisbon had the highest intake of protein because of their high intake of meat and fish, as opposed to the patients from Rotterdam who had a low consumption of these food groups, thus reporting the lowest protein intake.

Children from Milan presented a low intake of fat as a result of a small intake of meat and processed products. On the other hand, children from Madrid and Valencia had a higher intake of fat due to the high consumption of oil; consequently, they had the highest MUFA intakes. The Belgian patients achieved a similar fat intake, but mainly from processed products and solid fats. Low intake of PUFA was related to low intake of fish and nuts. The main sources of PUFA intake were meat and sweets and snacks.

Findings from the present study may have implications for clinical practice. The identification of the dietary origin of nutrients might serve as a basis for more targeted dietary interventions that include counseling patients on strategies to achieve the recommended nutritional intake and how to follow national recommendations for a healthy diet. To support patients in their efforts to achieve the recommended dietary intake, counsellors should provide information on dietary recommendations as well as exploring barriers to changing dietary intake and then tailor strategies to address identified barriers. Further, future actions should include the investigation of which strategies would be most effective for improving diet quality in children with CF.

Overall, the general recommendations according to the results of this study are to: (1) reduce SFA intake and increase PUFA intake by means of replacing the consumption of sweets and snacks with nuts and increasing fish intake; (2) reduce sugar intake by limiting the consumption of sweets and snacks and replacing them with fruit; (3) increase protein intake by increasing the consumption of fish and nuts; (4) increase fiber intake by promoting the consumption of legumes, vegetables, and nuts. Following these recommendations would likely lead to important modifications in dietary intake;

therefore individualized counseling by dietitians seems necessary. Moreover, based on the nutrient profiles reported in this study, the experts involved in the MyCyFAPP project have developed a nutritional recommendation handbook in which general and country-specific practical tips and examples are provided [31].

This study had several methodological strengths. First, participants were instructed to keep detailed food records by using four-day food records specifically developed for this study. According to different bodies (e.g., the European Food Consumption Survey Method [EFCOSUM] project [32] and the new European CF guidelines [5]), the food record method is applicable in large European populations and can be considered the best method to obtain a population's mean nutritional intakes and distributions [23], although it can lead to possible bias associated with self-report of dietary intake. The second and complementary strength is that a tailored nutritional composition database was used for the calculations, including food group categories, the whole range of macronutrients, and a few micronutrients. Differences in food groups and nutritional ingredients and definitions were reconciled and revised according to agreed common criteria among the different countries, which overall allowed for a reliable comparison among populations. This is a crucial point because, previously, the methods to measure food intake were not standardized across Europe, and intake data was generally poor, with uncertainties about the true nutrient intakes of children and adolescents [33]. Indeed, a recent study comparing the food intake among populations of two multicenter projects encountered a major limitation for the comparison, precisely because of the lack of a common criterion to classify food items into groups [34].

A limitation of the present study is the lack of standardized criteria for recommended food group intake in European countries, as previously acknowledged by the World Health Organization (WHO) (food-based dietary guidelines in the WHO European region [35]). The nutritional intake recommendations are frequently based on different units and expressed differently in various countries, such as the number of times or pieces [35]. Therefore, comparative analyses to a common standard or to national recommendations cannot be performed adequately. Another limitation is related to the small amount of information regarding micronutrient content in the product labels and in some of the nutritional composition databases (NCDBs); therefore, in the NCDBs used in the present study, the content often had to be estimated or extrapolated from similar products. Similarly, the lack of specific information about the type of sugar limited the estimation of the impact of “added” or “free” sugar to the diet [18], which should be <5% of the total daily energy intake [34]. However, some assumptions can be made; for example, all sugar from the fruit group is intrinsic, and most of the sugar from the sweets and snacks group is added. The main limitation, however, would be the differentiation between lactose and added sugar in milk and dairy products.

CONCLUSION

This study provides a description of nutrients and food group intake by children and adolescents with CF from different European countries. Nutrient profiles were sub-optimal in all of the centers, especially in relation to sugars and saturated fatty acids intake. This resulted from high intakes of processed foods, meat, and dairy, and a low consumption of fish, nuts, and legumes.

Future research should investigate possible barriers to adherence to dietary recommendations and develop strategies to improve diet quality in children with CF.

REFERENCES

1. Baker, RD. Assessing exocrine pancreatic function : when the best test is not possible. *J Pediatr Gastr and Nutr*. 2013;56(2):116–117.
2. Rovner AJ, Schall JI, Mondick JT, Zhuang H, Mascarenhas MR. Delayed small bowel transit in children with cystic fibrosis and pancreatic insufficiency: Commentary. *Inflamm. Bowel Dis. Monit.* 2014;14(1):65–66.
3. Woestenenk JW, van der Ent CK, Houwen RHJ. Pancreatic Enzyme Replacement Therapy and Coefficient Cystic Fibrosis. *J. Pediatr. Gastroenterol. Nutr*. 2015;61(3):355–360.
4. Borowitz D, Konstan MW, O'Rurke A, Cohen M, Hendeles L, Murray FT. Coefficients of Fat and Nitrogen Absorption in Healthy Subjects and Individuals with Cystic Fibrosis. *J Pediatr Pharmacol Ther*. 2007;12(1):4-9.
5. Turck D, Braeger CP, Colombo C, et al. ESPEN-ESPGHAN-ECFS guidelines on nutrition care for infants, children, and adults with cystic fibrosis. *Clin. Nutr.* 2016;35(3):557-577
6. Panagopoulou P, Fotoulaki M, Nikolaou A, Nousia-arvanitakis S. Prevalence of malnutrition and obesity among cystic fibrosis patients. *Pediatr. Int.* 2014;56(1):89-94.
7. Hanna RM, Weiner DJ. Overweight and obesity in patients with cystic fibrosis: A center-based analysis. *Pediatr. Pulmonol.* 2015 50():35–41.
8. World Health Organization. Programmes and projects. Population nutrient intake goals for preventing diet-related chronic diseases. https://www.who.int/nutrition/topics/5_population_nutrient/en/index12.html . Published May 2018. Accessed December 2018.

9. Guideline, WHO. Sugars intake for adults and children. Geneva: World Health Organization. 2015

10. Sutherland RE, Collins C, Brunner R, Ooi CY, Katz TE. An historical perspective of dietary intake studies in children with CF. 2017 *J. Cyst. Fibros.* 2017;16:S143.

11. Calvo-Lerma J, Martínez-Jiménez CP, Lázaro JP, et al. Innovative approach for self-management and social welfare of children with cystic fi brosis in Europe : development, validation and implementation of an mHealth tool (MyCyFAPP). *Br. Med. J. Open*. 2017;7:e014931

12. Calvo-Lerma J, Hulst J, Asseiceira I, et al. Nutritional status, nutrient intake and use of enzymatic supplements in paediatric patients with Cystic Fibrosis; a multicentre study with reference to current guidelines. *J. Cyst. Fibros*. 2017;16(4):510-518

13. BEDCA, Base de datos Española de Composición de Alimentos; 2009. htpps://www.bedca.net. Updated August 2010. Accessed January 2017

14. PortFIR, Tabela de Composição dos Alimentos; http://portfir.insa.pt/#. Accessed January 2017

15. BDA, Banca Dati di Composizione degli Alimenti. http://www.bda-ieo.it/wordpress/en/?page_id=45. Accessed January 2017

16. Nevo, Dutch Food Composition Database; 2011. https://www.rivm.nl/en/Topics/D/Dutch_Food_Composition_Database. Last update September 2016. Accessed January 2017

17. Nubel, Belgian Branded Food Products Database http://www.internubel.be/Login.aspx?lId=3. Accessed January 2017

18. Mis NF, Braegger C, Bronsky J, Campoy C, Domellöf M, Embleton ND,

Hojsak I, Hulst J, Indrio F, Lapillonne A, Mihatsch W, Molgaard C, Vora R, Fewtrell M, ESPGHAN Committee on Nutrition. Sugar in infants, children and adolescents: a position paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. *JPGN*, 2017;65(6): 681-696.

19. Kellett E, Smith A, & Schmerlaib Y. The Australian guide to healthy eating. Commonwealth Department of Health and Family Services. 1998

20. England, P. H. The Eatwell Guide. *London, UK: Public Health England*. 2016

21. de Dietética, S. E., & de la Alimentación, C. La nueva Rueda de los Alimentos. 2007

22. R Core Team [computer program]. Version 3.5.1. R Foundation for Statistical Computing, Vienna, Austria. R: A language and environment for statistical computing; 2013

23. Brown K, Mcilveen H, Strugnell C. Nutritional awareness and food preferences of young consumers. *Nutr & Food Sci*, 2000;30(5):230-235

24. Braithwaite I, Stewart AW, Hancox RJ et al. Body Mass Index and vigorous physical activity in children and adolescents: an international cross-sectional study. *Act Paed*. 2017;106(8):1323-1330

25. Huybrechts I, Matthys C, Vereecken C, Maes L, Temme EHM, Van Oyen H, De Backer G, De Henauw S. Food Intakes by Preschool Children in Flanders Compared with Dietary Guidelines. *Int. J. Environ. Res. Public Health*. 2008;5(4):243-257

26. Moreira P, Santos S, Padrão P, Cordeiro T, Bessa M, Valente H, Barros R, Teixeira V, Mitchell V, Lopes C, Moreira A. Food Patterns According to

Sociodemographics, Physical Activity, Sleeping and Obesity in Portuguese Children. *Int. J. Environ. Res. Public Health*. 2010;7(3):1121-1138

27. Pérez-Rodrigo C, Gil A, González-Gross M, Ortega RM, Serra-Majem L, Varela-Moreiras G, Aranceta-Bartrina, J. Clustering of Dietary Patterns, Lifestyles, and Overweight among Spanish Children and Adolescents in the ANIBES Study. *Nutrients*. 2015:8(1);11
28. De Jong-Rubingh C, & Bausche-Goldbohm RA. De Eet Compleet Test: 2-daags voedselconsumptie onderzoek onder kinderen van 1-4 jaar die een kinderdagverblijf bezoeken. *Zeist: TNO*. 2015
29. Roccaldo R, Censi L, D'Addezio L, Toti E, Martone D, D'Addesa D & The ZOOM8 Study Group. Adherence to the Mediterranean diet in Italian school children (The ZOOM8 Study). *Int J Food Sci & Nutr.* 2014;65(5):621-628.
30. Sutherland R, Katz T, Liu V, et al. Dietary intake of energy-dense, nutrient-poor and nutrient-dense food sources in children with cystic fibrosis. *J Cyst Fibros*. 2018;ahead of print
31. MyCyFAPP Project. Nutritional Recommendations Guideline for CF patients. CORDIS, *Community Research and Development Information Service, European Union*. https://cordis.europa.eu/project/rcn/194105_en.html. 2017
32. Biró G, Hulshof K, Ovesen L, Amorim, JA. Selection of methodology to assess food intake. *Eur. J. Clin. Nutr*. 2002;56(S2):S25
33. Lambert J, Agostini C, Elmadfa I, et al. Dietary intake and nutritional status of children and adolescents in Europe. *Br J Nutr.*

2004;92(S2):S147-S211

34. Stefler D, Pajak A, Malyutina S, Kubinova R, Bobak M, Brunner EJ. Comparison of food and nutrient intakes between cohorts of the HAPIEE and Whitehall II studies. *The European Journal of Public Health*. 2015;26(4):628-634

35. Food based dietary guidelines in the WHO European Region. 2004.

FIGURE LEGENDS

Figure 1. Contribution of food groups to daily total protein intake in a multicenter pediatric population of children with cystic fibrosis (n= 207). Dots represent the mean % of total protein coming from a food group/day.

Figure 2. Contribution of food groups to daily total carbohydrates (red area) and sugar (blue area) intake in a multicenter pediatric population of children with cystic fibrosis (n= 207). Dots represent the median % of total carbohydrates/sugars coming from a food group/day.

Figure 3. Contribution of food groups to daily total fat intake (red area), and to SFA (blue area), PUFA (green area) and MUFA (yellow area) intake in a multicenter pediatric population of children with cystic fibrosis (n= 207). Dots represent the median % of total fats coming from a food group/day.

Figure 4. Contribution of food groups to daily total macronutrient intake in a multicenter pediatric population of children with cystic fibrosis considered as a whole (n= 207). Dots represent the median % of total macronutrient coming from a food group/day.