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Higher adherence to the Mediterranean Diet is associated with lower micronutrient inadequacy in children: the SENDO project

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Abstract

Objective: To assess whether the Mediterranean Diet (MedDiet) is associated with lower micronutrients inadequacy in a sample of Spanish preschoolers.
Design: We conducted a cross-sectional study with 4–5-year-old children participating in the SENDO project. Information was gathered through an online questionnaire completed by parents. Dietary information was collected with a previously validated semi-quantitative FFQ. The estimated average requirements or adequate intake levels as proposed by the Institute of Medicine were used as cut-off point to define inadequate intake.
Statistical analyses: Crude and multivariable adjusted estimates were calculated with generalised estimated equations to account for intra-cluster correlation between siblings.
Participants: We used baseline information of 1153 participants enrolled in the SENDO project between January 2015 and June 2022.
Main outcomes measures: OR and 95 % CI of presenting an inadequate intake of ≥ 3 micronutrients associated with the MedDiet.
Results: The adjusted proportion of children with inadequate intake of ≥ 3 micronutrients was 27·2 %, 13·5 % and 8·1 % in the categories of low, medium and high adherence to the MedDiet, respectively. After adjusting for all potential confounders, children who had a low adherence to the MedDiet showed a significant lower odds of inadequate intake of ≥ 3 micronutrients compared to those with a high adherence (OR 9·85; 95 % CI 3·33, 29·09).
Conclusion: Lower adherence to the MedDiet is associated with higher odds of nutritional inadequacy.

Keywords
Breast-feeding
Micronutrients
Diet quality
Children

In recent years, nutritional science has shifted from a reductionist paradigm, mainly focused on single nutrients, to a more holistic approach to diet that considers global dietary quality[1]. Most international dietary guidelines now endorse a dietary pattern approach, moving away from quantitative nutrient advice[2].

The 2020–2025 Dietary Guidelines for Americans define a dietary pattern as 'the quantities, proportions, variety, or combination of different foods, drinks, and nutrients in diets, and the frequency with which they are habitually consumed'[3]. This better reflects the relation between food and health, including in the equation the complex interactions of nutrients and non-nutrients within our organism. Moreover, it presents clear advantages in clinical practice and in terms of public health messages, as it is more easily translatable to the general population than the traditional quantitative measures, that made guidelines hard to grasp and adherence low[2,4].

Among the dietary patterns with the greatest scientific consensus, the Mediterranean Diet (MedDiet) has been recognised as one of the healthiest diets worldwide, as evidence has shown to protect against multiple chronic

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diseases and increase life expectancy[5–8]. The MedDiet is characterised by a high consumption of plant-based foods, moderate-to-high consumption of fish and low consumption of meat and dairy products (with the exception of yogurt and long preservable cheeses). Nevertheless, the hallmark of the MedDiet is the liberally consumed olive oil (or extra virgin olive oil), which represents its main culinary fat[9]. These foods make the MedDiet be rich in micronutrients, fibre, antioxidants and healthy fats and therefore a stellar candidate to achieve nutritional adequacy.

Micronutrients are vitamins and minerals involved in multiple functions such as the production of enzymes and hormones[10]. An insufficient dietary intake of micronutrients leads to a depletion of body reserves which, if maintained, is followed by a decrease in serum levels and then by clinical impairment. Although severe deficits are more frequent in low-income countries, inadequate micronutrient intake is frequent in middle- and high-income countries[11,12].

Suboptimal nutrition is a key concern in children around the world[13,14], including Spain[15]. Evidence has shown that the MedDiet enhanced nutritional adequacy in adult populations[16], but, to our knowledge, few studies have studied this association in children, and none in preschoolers particularly. For this reason, we investigated the association between adherence to the MedDiet and nutrient adequacy in a population of Spanish preschoolers.

Materials and methods

Study population

The *Seguimiento del Niño para un Desarrollo Óptimo* (SENDO) project is an ongoing Spanish prospective cohort focused on the study of the effect of diet and lifestyle on the health of children and adolescents. The recruitment is permanently open. Participants are invited to enter the cohort by their paediatrician at their primary care health centre or by the research team at school. The cohort has the following inclusion criteria: (1) children of 4 or 5 years of age and (2) residing in Spain. The sole exclusion criterion is the lack of access to an internet-connected device to complete the questionnaires. Information is collected at baseline and updated every year through self-administered online questionnaires, which are completed by parents. For this study, we used baseline information of participants recruited between January 2015 and June 2022. Of the 1153 participants in the SENDO project recruited up to June 2022, 138 were excluded for presenting energy values > p99 or < p1, 111 for presenting implausible micronutrient intake values (mean ± 3 SD) and 81 for not having completed the baseline questionnaire. A total of 819 preschoolers were finally included (Fig. 1).

The SENDO project follows the rules of the Helsinki Declaration on Ethical Principles for Human Research, and its protocol was approved by the Ethical Committee for Clinical Research of Navarra (Pyto 2016/122). Participants' parents or legal guardians signed an informed consent before entering the study.

Assessment of the exposure

Dietary information was collected at baseline with a previously validated 147-item semi-quantitative FFQ[17]. A portion size was specified for each food item. Parents reported how often their child had consumed each of the food items over the previous year by choosing one out of the nine options of response ranging between 'never/almost never' and '≥ 6 times/day'. The nutrient content of each food item was calculated by trained dietitians, by multiplying the frequency of consumption by the edible portion and the nutrient composition of the specified portion size. Updated Spanish food composition tables[18] and online information[19] were used for this purpose. Total energy intake was obtained by adding the calorie contribution of each item.

Diet quality was assessed with the KIDMED index, an a priori-defined dietary index to evaluate the adherence to the MedDiet pattern in children and adolescents[20]. The KIDMED index consists of sixteen items, of which twelve items score 0 or +1 and four items score –1 or 0. Thus, the score in the KIDMED index may range from –4 to 12 points. Participants' adherence to the MedDiet was classified as poor (≤ 3 points), medium (4–7 points) or high (≥ 8 points) according to their score[21,22].

Assessment of the outcome

We determined micronutrient intake adequacy for twenty micronutrients of known public health relevance, Zn; I; Se; Fe; Ca; K; P; Mg; Cr; Na; vitamin B_1; vitamin B_2; vitamin B_3; vitamin B_6; folic acid, vitamin B_{12}; vitamin C; vitamin A; vitamin D and vitamin E. To calculate the probability of intake adequacy, we compared the intakes of these nutrients with the estimated average requirements (EAR) when these were available or adequate intake levels, if not, as proposed by the Institute of Medicine[23]. The traditional[24] and probabilistic[25] approaches were used. In the latter, the probability of adequacy for the usual intake of a nutrient was estimated from a z-score calculated as (derived nutrient intake - EAR)/SD of the EAR.

Evaluation of covariates

The baseline questionnaire collected information on sociodemographic and lifestyle variables, including physical activity and sedentary behaviour, as well as on personal and family medical records.

BMI was calculated using the ratio of reported weight (kg) to squared height (m^2). The weight and height of the SENDO project participants reported by parents had been previously validated[26]. Nutritional status was defined using sex- and age-specific BMI cut-off points based on International Obesity Task Force reference standards[27].

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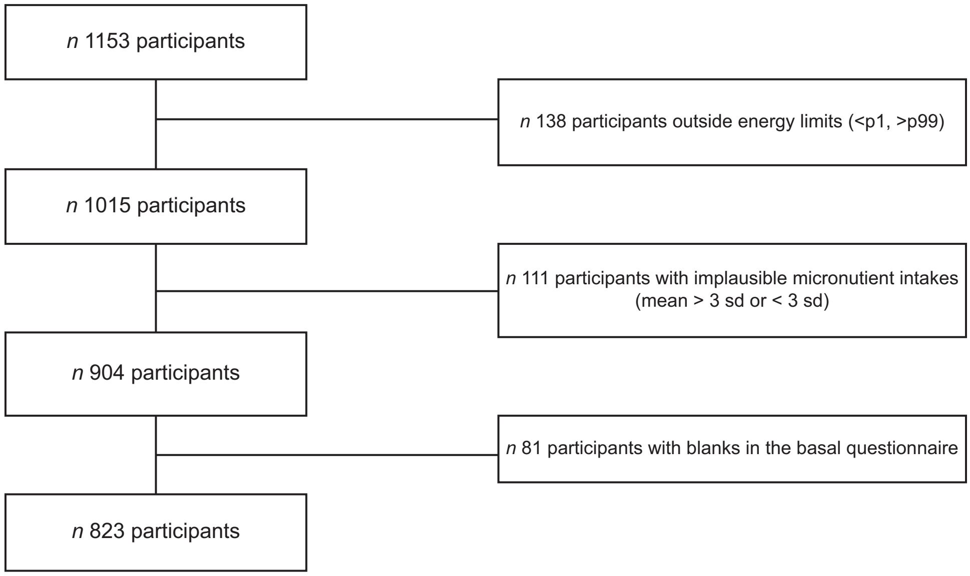

Fig. 1 Flow chart of participants

Physical activity was collected with a questionnaire that included seventeen activities and ten response categories, from never to ≥ 11 h/week. The Metabolic Task Equivalent (MET)-h/week for each activity was calculated by multiplying the number of MET of each activity by the weekly participation in that activity, weighted according to the number of months dedicated to each activity[28]. Total physical activity was quantified by adding the MET-h/week of all the activities carried out during free time. Screen time was calculated as the average number of hours per day dedicated to watching TV, using a computer or playing video games. Parental knowledge of nutritional recommendations for children was assessed with questions about the recommended intake frequency of ten food groups (i.e. fruit, vegetables, dairy products). Parents had to choose among ten categories of response ranging from 'Never/ Almost never' to '≥ 6 or more times/day'. Each question was assigned 1 point if the answer complied with dietary recommendations and 0 points if not. The final score was expressed as a percentage, with a higher value meaning better knowledge about nutritional recommendations for children. For analysis, participants' knowledge was categorised as low (< 40 %), moderate (40–70 %) or high (> 70 %). Parental attitudes towards their child's dietary habits were assessed with an 8-item questionnaire (i.e. I try to support my child to eat more fruit; I try to support my child to reduce the consumption of candies). Each question was assigned 1 point if the answer complied with dietary recommendations and 0 points if not. For analysis, parental attitudes were categorised as unhealthy (0–3 points), average (4–5 points) or healthy (6–8 points). Given the possibility of a change in diet due to the COIVD-19 pandemic, we divided the participants according to whether they completed the questionnaire before or after the declaration of the state of alarm in Spain (14 March 2020).

Statistical analysis

Participants' socio-demographic characteristics were compared according to MedDiet adherence (low, medium or high). For descriptive purposes, we used means and standard deviations for quantitative variables and percentages for categorical ones. Nutritional characteristics of children's diet were also described and compared according to their adherence to MedDiet.

In the main analyses, we calculated the OR and 95 % CI for failing to meet the EAR of ≥ 3 micronutrients associated with the adherence to the MedDiet. The high adherence was used as the reference category. Crude and multivariate adjusted estimates were calculated through three progressively adjusted models. The first model was adjusted for sex (male or female), race (white *v.* others), nutritional status (underweight, normal weight, overweight/obese), total energy intake (quintiles), breast-feeding duration (no, < 6 months, 6–12 months, > 12 months) and pre- and post-pandemic compliance, number of children and position held among siblings. The second model was adjusted for all the variables in model 1 plus maternal age (< 35 years, 35–40 years, > 40–45 years, > 45 years), maternal higher education (yes or no), parental knowledge about children's nutritional recommendations (low, medium or high score) and parental attitudes towards their child's dietary habits (unhealthy, average, healthy). Finally, the third model was adjusted for all the variables in models 1 and 2 plus physical activity (quintiles) and screen time (continuous).

Finally, we calculated the marginal effect of the adherence to the MedDiet, that is, the adjusted proportion

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Table 1 Main characteristics of children in the SENDO project and their families (January 2015–June 2022). Numbers are mean (SD) or %

	Low adherence		Medium adherence		High adherence		
	n or Mean	% or SD	*n* or Mean	% or SD	*n* or Mean	% or SD	$P_{for\ trend}$
n	80	9·7 %	565	68·7 %	178	21·6 %	
Children's characteristics							
Sex (boys)	43	53·75	274	48·50	87	48·88	0·68
Age (years)	4·86	0·83	5·06	0·87	4·87	0·75	0·37
Race (White)	76	95·00	545	96·46	173	97·19	0·40
Screen time (h/d)	1·39	1·14	1·09	0·82	1·03	1·23	0·01
Physical activity (MET-h/d)	31·66	21·29	40·78	29·68	44·01	30·09	< 0·01
Birth weight (g)	3164·81	608·3	3240·06	548·5	3226·08	501·2	0·60
Breast-feeding duration							< 0·01
No breast-feeding	19	23·75	102	18·05	16	8·99	
< 6 months	33	41·25	159	28·14	45	25·28	
6–12 months	15	18·75	142	25·13	55	30·90	
> 12 months	13	16·25	162	28·67	62	34·83	
Z-score of BMI	0·11	1·09	0·05	1·17	0·04	1·10	0·68
Energy intake (kcal)	1720·84	447·2	2035·19	456·2	2180·51	458·5	< 0·01
Family characteristics							
Mother's age (years)	39·45	4·32	39·97	4·40	39·95	4·27	0·52
Maternal higher education	58	72·50	460	81·42	151	84·83	0·06
Number of children							0·67
1–2	60	75·00	358	63·36	123	69·10	
3	14	17·50	116	20·53	31	17·42	
≥ 4	6	7·50	91	16·11	24	13·48	
Position held among siblings							0·44
The oldest or singleton	25	31·25	207	36·64	66	37·08	
2nd/3 or 2nd–3rd/4	7	8·75	97	17·17	22	12·36	
The youngest or ≥ 4th	48	60·00	261	46·19	90	50·56	
Parental knowledge about dietary recommendations for children							0·02
Low (< 40 %)	24	30·00	132	23·36	30	16·85	
Medium (40–70 %)	49	61·25	364	64·42	113	63·48	
High (> 70 %)	7	8·75	69	12·21	35	19·66	
Parental attitudes towards child's dietary habits							< 0·01
Unhealthy (0–3 points)	13	16·25	24	4·25	6	3·37	
Average (4–5 points)	41	51·25	187	33·10	40	22·47	
Healthy (6–8 points)	26	32·50	354	62·65	132	74·16	

(and 95 % CI) of children with inadequate intake of ≥ 3 micronutrients in each category of adherence to the MedDiet.

To carry out a sensitivity analysis, calculations were repeated using the probabilistic method. A second sensitivity analysis was performed by adding to the micronutrient intake the content of the supplements reported by the participants.

Analyses were carried out using Stata 15.0 (Stata Corporation). All *P*-values are two-tailed. Statistical significance was established at the conventional cut-off point of $P < 0·05$.

Results

The main characteristics of participants and their parents are shown in Table 1. In this sample, 565 (68·7 %) participants showed a medium adherence to the MedDiet, representing the largest group. Children with greater adherence to the MedDiet also presented overall healthier lifestyle indicators, such as less exposure to screens ($P = 0·01$) and more time being physically active ($P < 0·01$), but also higher energy intake ($P < 0·01$). Similarly, longer breast-feeding duration was associated with greater adherence to the MedDiet ($P < 0·01$), which had previously been reported in this cohort[29]. Parents who fed their children according to the MedDiet pattern showed greater knowledge about children's dietary recommendations ($P = 0·02$) and displayed healthier attitudes towards their child's dietary habits ($P < 0·01$). Maternal education was marginally associated with higher adherence to MedDiet in this sample ($P = 0·06$).

Nutritional characteristics of the children's diet based on their adherence to the MedDiet are shown in Table 2. Children with the highest adherence to the MedDiet reported significantly higher ($P < 0·001$) consumption of carbohydrates, fibre, vegetables, fruit, legumes, cereals, potatoes, fish, nuts and eggs. On the contrary, those children presented significantly lower ($P < 0·001$) consumption of SFA and PUFA, fast food ($P = 0·026$) and other fats ($P = 0·002$).

We found significant associations between MedDiet adherence and energy-adjusted intake for seventeen out of

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Table 2 Nutritional characteristics of children in the SENDO project (January 2015–June 2022) according to their level of adherence to the Mediterranean diet. Numbers are mean (SD) or %

	Low adherence		Medium adherence		High adherence		
	n or Mean	% or SD	*n* or Mean	% or SD	*n* or Mean	% or SD	$P_{for\ trend}$
n	80	9·7 %	565	68·7 %	178	21·6 %	
Total energy intake (kcal/d)	1720·84	447·2	2035·19	456·2	2180·51	458·5	< 0·001
Carbohydrate intake (% of TEI)	41·78	5·61	43·19	5·12	44·70	5·06	< 0·001
Protein intake (% of total energy)	17·24	2·17	17·12	2·20	16·82	1·98	0·079
Fat intake (% of total energy)	40·97	5·78	39·69	5·19	38·48	5·07	< 0·001
SFA intake (% of total energy)	12·00	2·24	11·29	2·12	10·48	1·98	< 0·001
MUFA intake (% of total energy)	15·19	3·99	15·31	3·50	15·36	3·19	0·734
PUFA intake (% of total energy)	5·39	1·84	4·62	1·03	4·55	0·92	< 0·001
SFA/MUFA intake	1·28	0·31	1·38	0·32	1·50	0·34	< 0·001
Fibre intake (g/d)	13·84	4·55	20·49	5·56	25·74	5·99	< 0·001
Food groups							
Vegetables (g/d)	84·83	52·0	186·7	102·4	255·6	98·8	< 0·001
Fruits (g/d)	201·5	186·3	357·7	196·2	500·6	219·8	< 0·001
Legumes (g/d)	21·64	15·04	32·36	18·35	36·04	17·64	< 0·001
Dairy (g/d)	435·6	249·7	490·3	237·5	482·5	233·4	0·326
Cereals (g/d)	59·54	30·27	75·63	38·30	88·44	39·12	< 0·001
Potatoes (g/d)	12·53	14·16	18·52	19·64	21·70	18·23	< 0·001
Meat (g/d)	126·22	41·56	134·74	45·53	131·17	47·96	0·778
Fish (g/d)	28·22	13·67	35·18	17·11	38·20	15·58	< 0·001
Nuts (g/d)	3·75	9·39	4·64	5·96	8·31	10·6	< 0·001
Bakery and sweets (g/d)	80·00	47·65	83·64	57·98	73·72	48·78	0·156
Sugar-sweetened beverages (g/d)	48·06	86·03	45·86	78·51	35·93	52·74	0·134
Fast Food (g/d)	58·95	28·62	60·26	26·61	54·85	32·25	0·098
Eggs (g/d)	16·74	9·26	19·64	10·25	21·35	7·78	0·001
Olive oil (g/d)	7·61	11·63	10·54	13·34	10·57	12·95	0·196
Other fats (g/d)	4·17	5·51	2·56	3·71	2·28	2·89	0·002

Table 3 Energy-adjusted micronutrient intake of children in the SENDO project (January 2015–June 2022) according to their level of adherence to the Mediterranean diet. Numbers are mean (SD)

	Low adherence		Medium adherence		High adherence		
	n or Mean	% or SD	*n* or Mean	% or SD	*n* or Mean	% or SD	$P_{for\ trend}$
n	80	9·7 %	565	68·7 %	178	21·6 %	
Micronutrients							
Vitamin A (μg/d)	797·54	48·10	1045·43	17·69	1270·93	31·86	< 0·01
Vitamin C (mg/d)	78·62	6·26	135·44	2·30	180·54	4·15	< 0·01
Vitamin D (μg/d)	2·70	0·19	3·06	0·07	3·60	0·13	< 0·01
Vitamin E (mg/d)	8·96	0·31	8·08	0·11	8·97	0·20	0·15
Vitamin B_1 (mg/d)	1·26	0·03	1·43	0·01	1·53	0·02	< 0·01
Vitamin B_2 (mg/d)	1·83	0·05	2·07	0·02	2·07	0·04	< 0·01
Vitamin B_3 (mg/d)	30·82	0·83	35·65	0·31	38·46	0·55	< 0·01
Vitamin B_6 (mg/d)	1·89	0·05	2·27	0·02	2·55	0·03	< 0·01
Folic Acid (μg/d)	234·92	8·21	295·21	3·02	349·64	5·44	< 0·01
Vitamin B_{12} (mg/d)	4·32	0·15	4·69	0·05	4·79	0·10	0·02
Ca (mg/d)	1155·45	28·47	1166·86	10·47	1184·68	18·86	0·34
I (μg/d)	99·94	2·58	110·21	0·95	111·65	1·71	< 0·01
Fe (mg/d)	12·37	0·23	13·85	0·08	15·00	0·15	< 0·01
P (mg/d)	1481·65	72·55	1716·02	26·69	1902·35	48·06	< 0·01
Mg (mg/d)	258·18	4·77	296·08	1·75	328·91	3·16	< 0·01
Se (μg/d)	69·15	1·50	71·69	0·55	74·00	0·99	< 0·01
Zn (mg/d)	8·78	0·22	9·68	0·08	9·82	0·15	< 0·01
Cr (μg/d)	58·16	2·26	67·00	0·83	74·56	1·50	< 0·01
K (mg/d)	2828·53	64·08	3365·96	23·57	3793·19	42·44	< 0·01
Na (mg/d)	2902·25	96·13	2982·91	35·36	2921·13	63·68	0·84

the twenty micronutrients analysed, all except for vitamin E, Ca and Na. Of the micronutrients showing an association with MedDiet adherence, all showed a positive correlation (Table 3).

The spline at the top of Fig. 2 shows that, after adjusting for all the potential confounders, the change in micronutrient inadequacy (solid line) and the 95 % CI (dashed line) associated with the increase in MedDiet adherence

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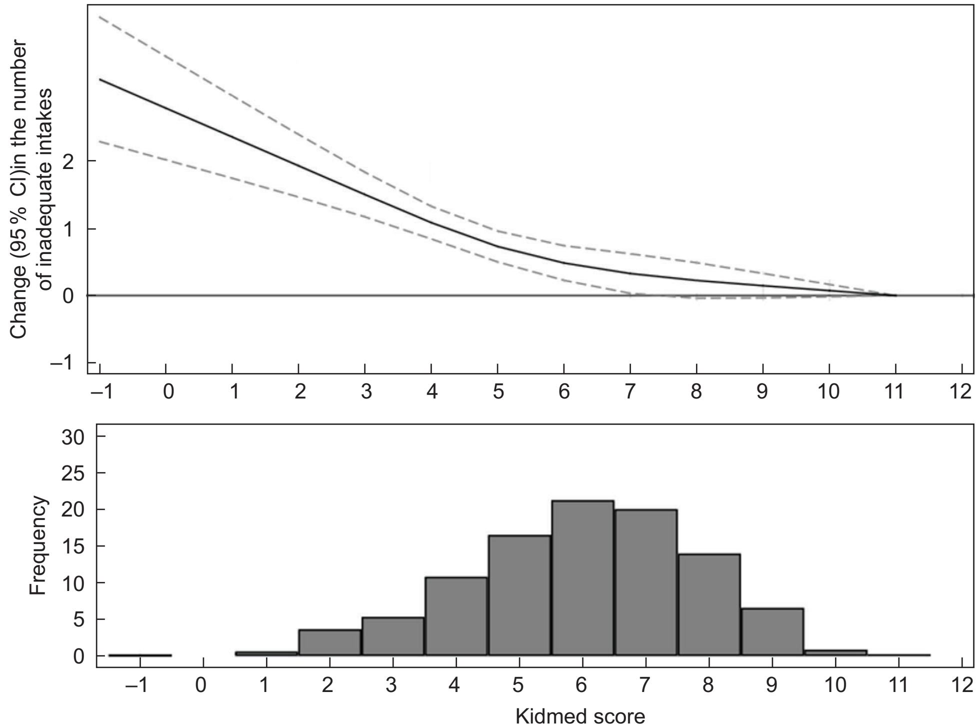

Fig. 2 The spline at the top shows that, after adjusting for all the potential confounders, the change in micronutrient inadequacy (solid line) and the 95 % CI (dashed line) associated with the increase in MedDiet adherence (assessing this variable as continuous) displayed a linear trend. MedDiet, Mediterranean Diet

Table 4 OR and 95 % CI of failing to meet ≥ 3 micronutrients recommendations associated with adherence to the Mediterranean diet using the traditional method to define inadequate intake

	Low adherence		Medium adherence		High adherence		
	OR	95 % CI	OR	95 % CI	OR	95 % CI	$P_{\text{for trend}}$
n	80		565		178		
%	9·7 %		68·7 %		21·6 %		
Crude	21·30	9·36, 48·49	3·13	1·52, 6·45	1·00 (Ref.)		< 0·01
Multivariable adjusted model 1	12·74	4·76, 34·12	2·51	1·08, 5·86	1·00 (Ref.)		< 0·01
Multivariable adjusted model 2	10·89	3·73, 31·79	2·36	1·00, 5·53	1·00 (Ref.)		< 0·01
Multivariable adjusted model 3	9·85	3·33, 29·09	2·23	0·94, 5·29	1·00 (Ref.)		< 0·01

Model 1 is adjusted for sex (male or female), age (continuous), nutritional status (underweight, normal weight, overweight/obese), total energy intake (kcal), breast-feeding (no, < 6 months, 6–12 months, > 12 months) and pre- and post-pandemic compliance, number of children and position held among siblings.
Model 2 is additionally adjusted for maternal age (< 35 years, 35–40 years, > 40–45 years, > 45 years), maternal higher education (yes or no), parental knowledge about child's nutritional recommendations (low, medium score or high) and parental attitudes towards child's dietary habits (unhealthy, average, healthy).
Model 3 is additionally adjusted for physical activity (tertiles) and screen time (tertiles).

(assessing this variable as continuous) displayed a linear trend. The regression analysis showed a slope of –0·26, meaning that, for every four extra points on the KIDMED index, there was a decrease of 1 micronutrient for which the intake was inadequate.

Table 4 represents the OR and 95 % CI for failing to meet the EAR for ≥ 3 micronutrients associated with the adherence to the MedDiet. Compared to participants with high adherence to the MedDiet, those with low and medium adherence showed 9·85-time (95 % CI 3·33, 29·09) and 2·23-time (95 % CI 0·94, 5·29), respectively, higher odds of having an inadequate intake of ≥ 3 micronutrients in the most adjusted model.

Figure 3 shows the marginal effect of the adherence to the MedDiet on the risk of failing to meet the EAR of ≥ 3 micronutrients. The adjusted proportion of children with ≥ 3 micronutrient inadequacies was significantly higher in the group of children with low adherence than in that with high adherence to the MedDiet. More specifically, the proportion of children who failed to meet the EAR of ≥ 3 micronutrient in the categories of low, medium and high adherence to the MedDiet was 27·3 % (95 % IC 19·3 % to 35·3 %), 13·5 % (95 % IC 11·1 % to 15·9 %) and 8·1 % (95 % IC 3·5 % to 12·8 %), respectively.

The robustness of these findings was assessed with two sensitivity analyses. The analysis that took into account the

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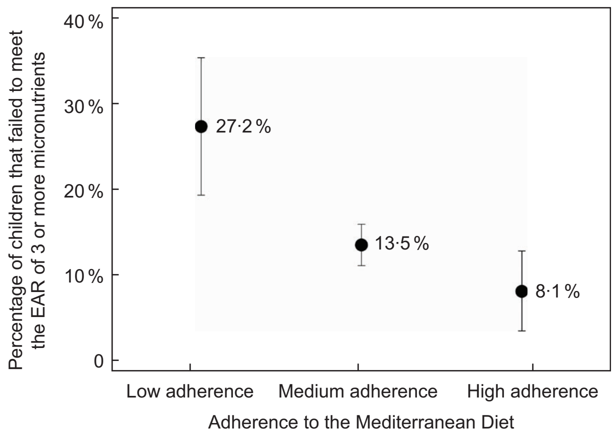

Fig. 3 Marginal effect of the adherence to the MedDiet on the risk of failing to meet the EAR of ≥ 3 micronutrients. MedDiet, Mediterranean Diet; EAR, estimated average requirement

content of the supplement intake reported by participants did not change the results (data not shown). On the other hand, the use of the probabilistic approach to define micronutrient inadequate intake resulted in higher estimates (see online supplementary material, Supplemental Table 1).

Discussion

This cross-sectional study based on 819 Spanish preschoolers examined the association between adherence to the MedDiet and micronutrient inadequacy. After adjusting for all the potential confounders, lower adherence to the MedDiet was directly associated with micronutrient inadequacy. Compared with children with high adherence to the MedDiet, those with medium or low adherence had 2·23 and 9·85-fold higher odds of failing to meet the EAR of 3 or more micronutrient, respectively.

To the best of our knowledge, this is the first study that focuses on the relation between the MedDiet and micronutrient inadequacy in young children. Our results are relevant from a public health perspective, given that a non-negligible prevalence of micronutrient inadequacy persists among children and adolescents around the world[13]. This is also the case in more affluent regions such as Europe and North America, as recent studies have shown[14,15,30–32].

These results are in line with previous findings, in both adults, adolescents and older children[16]. Moreover, as in the present study, a similar dose–response manner was found in previous ones[33–35].

In our study, greater KIDMED scores were associated with higher intakes of vitamin A, vitamin C, vitamin D, vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_6, vitamin B_{12}, folic acid, I, Fe, P, Mg, Se, Zn, Cr and K. Along with this, higher adherence to the MedDiet was associated with lower prevalence of inadequate intakes of vitamin A, vitamin C, vitamin E, folic acid, Ca, I, K and Na (see online supplementary material, Supplemental Table 2). Increased intakes of a similar group of micronutrients were observed with higher KIDMED scores in the studies by Serra-Majem *et al.* and by Peng *et al.* in populations of older children[33,35]. Those studies also showed reductions in several micronutrient inadequacies that did not come up in our study because our participants did not report inadequate intakes of those micronutrients to begin with. It is worth mentioning that a high proportion of the participants in this study displayed a medium or high adherence to the MedDiet and therefore had a good to excellent diet, with higher intakes of nutritious foods than the average Spanish children, as it stems from the comparison with population-based studies[31,36]. This could be due to different factors, one of them being that most of the participants in the SENDO project belong to highly educated families, which is a known characteristic of participants in cohort studies, who tend to be more health conscious[37].

As previous studies have shown, the Mediterranean dietary pattern is of a high nutritional quality and displays an excellent micronutrient profile[14,38,39]. Thus, it is reasonable to think that the improvement in nutritional adequacy observed in this study could be due to the high content of nutrient-dense foods that make up the MedDiet. In fact, children with the highest adherence to the MedDiet showed higher consumption of vegetables, fruits, legumes, nuts, fish and eggs. They also presented lower consumption of sugar-sweetened beverages and bakery and sweets, which are foods known to be high in calories but low in nutrients.

Although it is true that we found a study population with a higher pattern of adherence to the MedDiet than the mean of other population-based studies in the paediatric population[31,36], we consider that this is related to the fact that participants in cohort studies are usually health-conscious subjects with healthier lifestyles[37].

Overall, and despite its limitations, the KIDMED questionnaire appears to be useful to predict the risk of inadequate intake of micronutrients. The proportion of children with inadequate intakes decreased in a dose–response manner as adherence to the MedDiet improved. More importantly, this proportion was notably low in the high adherence category.

This study is subject to certain limitations. First, the observational nature of our study does not enable us to eliminate possible residual confounding by unknown factors. Nonetheless, the study's large sample size and the fact that a substantial amount of information was collected from the participants have made it possible to adjust for many potential confounders. Moreover, the fact that our participants have parents with a high educational level reduces the possibility of confounding by socio-economic factors[40] and improves the validity of the self-reported information. Second, since we used self-reported

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information, the existence of measurement errors cannot totally be ruled out. A measurement error could lead to a misclassification bias in either the exposure (adherence to the MedDiet) or the outcome (micronutrient intake). Regarding the former, the possibility of misclassification was reduced by classifying the participants in three categories of exposure. Regarding the latter, the FFQ used in this study had been previously validated(41), making measurement errors less likely. Additionally, since the participants did not know of the objective of the study, a potential misclassification bias would have been of the non-differential type, which would bias the results towards the null, making it more difficult to obtain statistically significant results. Fourth, our results refer to the probability of nutritional adequacy, not to actual nutrient deficiency, which can best be established through biomarkers of nutrient intake. Fifth, the sample of this study included only Spanish children, which may limit its external validity. However, we believe that the results could be generalised based on biological mechanisms and not based on statistical representativeness(42,43). Lastly, due to the observational design of the study, the possibility of residual confounding by variables we did not account for (such as economic status) must be considered.

On the other hand, our study has several strengths. The large sample size and the large amount of information collected from the participants enabled a better control of confounding than some of the previous studies. Second, we excluded participants with energy or micronutrient intakes out of predefined ranges to avoid information bias. Third, we accounted for intra-cluster correlation between siblings in all the analyses, which is a common limitation of studies in paediatric populations. Fourth, the observed results are constant throughout the sensitivity analyses.

In conclusion, we found that lower adherence to the MedDiet was associated with a higher risk of nutritional inadequacy. Given the persistence of suboptimal micronutrient intake around the world, the Mediterranean dietary pattern may represent a promising option that could serve as a reference for Public Health nutrition policies to prevent micronutrient inadequacies in the paediatric population.

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Conflict of interest

The authors declare no conflict of interest.

Authorship

All authors collected the data. A.O.O. and N.M.C. performed the statistical analyses. A.O.O. and E.F. wrote the first draft. All authors reviewed and commented on subsequent drafts of the manuscript.

Ethics of human subject participation

The SENDO project follows the rules of the Helsinki Declaration on Ethical Principles for Human Research, and its protocol was approved by the Ethical Committee for Clinical Research of Navarra (Pyto 2016/122). Participants' parents or legal guardians signed an informed consent before entering the study.

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980023002707

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