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Dietary Supplementation Before, During and After Pregnancy: Results of the Cluster-Randomized GeliS Study

Nährstoffsupplementierung vor, während und nach der Schwangerschaft: Ergebnisse der cluster-randomisierten „Gesund leben in der Schwangerschaft“-Studie

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ABSTRACT

Introduction The nutritional status of women before, during, and after pregnancy plays an important role in the health of mother and child. In addition to a balanced mixed diet, the increased need for folic acid and iodine should be met and ensured with supplements. The aim of this study was to assess dietary supplementation in the context of pregnancy and to investigate the effect of targeted counselling on supplementation behavior during and after pregnancy.

Methods In the context of the “Gesund leben in der Schwangerschaft” (GeliS; “Healthy living in pregnancy”) trial, women in the intervention group (IG) received four structured lifestyle counselling sessions during pregnancy as well as postpartum, during which they were informed about appropriate dietary supplementation. The women in the control group (CG) received routine prenatal care. The intake of dietary supplements was recorded at different points using a questionnaire.

Results In total, 2099 women were included in the analysis. Prior to conception, 31.3% of the women in the IG and 31.4% of the women in the CG took folic acid supplements. Prenatally, about half of the women took folic acid (IG: 54.1%; CG: 52.0%) and iodine (IG: 50.2%; CG: 48.2%).

Statistically significant differences between the groups with regard to supplementation behavior could not be observed, neither prior to inclusion in the study nor during the intervention. During pregnancy, 23.0% of all women took docosahexaenoic acid (DHA) supplements and 21.8% iron supplements. 49.4% of the women additionally took vitamin D supplements. A higher educational level ($p < 0.001$), advanced age ($p < 0.001$), primiparity ($p < 0.001$), and a vegetarian diet ($p = 0.037$) were all associated with a higher level of dietary supplementation.

Conclusion The GeliS lifestyle counselling did not significantly improve the supplementation behavior of women during and after pregnancy. Women should be informed about adequate dietary supplementation early on within the scope of gynecological prenatal care.

ZUSAMMENFASSUNG

Einleitung Der mütterliche Ernährungsstatus vor, während und nach der Schwangerschaft spielt eine wichtige Rolle für die Gesundheit von Mutter und Kind. Neben einer ausgewogenen Mischkost sollte der Mehrbedarf an Folsäure und Jod zusätzlich durch Supplemente sichergestellt werden. Ziel dieser Arbeit war es, die Nährstoffsupplementierung rund um die Schwangerschaft zu erfassen sowie den Einfluss einer gezielten Beratung auf das Supplementierungsverhalten während und nach der Schwangerschaft zu untersuchen.

Methoden Im Rahmen der „Gesund leben in der Schwangerschaft" (GeliS)-Studie erhielten Frauen der Interventionsgruppe (IG) 4 strukturierte Lebensstilberatungen in der Schwangerschaft und postpartal, in denen sie auch über eine angemessene Nährstoffsupplementierung informiert wurden. Die Frauen der Kontrollgruppe (KG) durchliefen die routinemäßige Schwangerenvorsorge. Die Einnahme von Nährstoffsupplementen wurde zu verschiedenen Zeitpunkten mithilfe eines Fragebogens erfasst.

Ergebnisse Insgesamt wurden 2099 Frauen in die Analyse eingeschlossen. Präkonzeptionell supplementierten 31,3% der Frauen der IG und 31,4% der Frauen der KG Folsäure. Pränatal nahm etwa die Hälfte der Frauen Folsäure (IG: 54,1%; KG: 52,0%) und Jod (IG: 50,2%; KG: 48,2%) ein. Weder vor Studieneinschluss noch während der Intervention bestanden statistisch signifikante Gruppenunterschiede im Supplementierungsverhalten. Während der Schwangerschaft supplementierten 23,0% aller Frauen Docosahexaensäure (DHA) und 21,8% Eisen. 49,4% der Frauen nahmen zusätzlich Vitamin D ein. Ein höherer Bildungsstand ($p < 0{,}001$), höheres Alter ($p < 0{,}001$), Primiparität ($p < 0{,}001$) und eine vegetarische Ernährungsweise ($p = 0{,}037$) waren mit einer höheren Nährstoffsupplementierung assoziiert.

Schlussfolgerung Die GeliS-Lebensstilberatung konnte das Supplementierungsverhalten der Frauen während und nach der Schwangerschaft nicht wesentlich verbessern. Frauen sollten im Rahmen der gynäkologischen Betreuung frühzeitig über eine adäquate Nährstoffsupplementierung aufgeklärt werden.

Introduction

Nutritional status in the context of a pregnancy plays an important role in the course of the pregnancy, both for the mother's health and for the development and long-term health of the child [1 – 3]. The current recommendations for women before, during and after pregnancy are based on recommendations by the nationwide "Healthy Start – Young Family Network" [4, 5], as well as on the general recommendations for a healthy adult diet [6]. For the most part, a varied and well-balanced mixed diet can meet the increased need for certain vitamins, mineral nutrients and trace minerals during pregnancy [4, 7]. However, this does not fully apply to all nutrients. The intake of folic acid and iodine, in particular, is an exception, as the additional need for both of these micronutrients is usually not met by the general dietary habits in Germany [4, 8, 9]. To prevent a deficiency of folic acid and iodine and ensure that the increased need is met, the recommendation is to begin taking supplements before or at the beginning of pregnancy [4]. The benefit of folic acid and iodine supplementation as a prevention strategy with regard to the health of mother and child has been sufficiently evidenced by scientific data [10 – 12]. Women planning a pregnancy should, according to the current recommendations, begin taking 400 µg additional folic acid daily, at the very latest four weeks prior to conception and until the end of the first trimester. If the folic acid supplementation was initiated less than four weeks prior to conception, then the dose should be increased [4]. Supplementing folic acid before conception and up to the end of the first trimester can significantly lower the risk of neural tube defects [10, 11]. In addition to folic acid, 100–150 µg of iodine should be taken daily during the pregnancy and 100 µg iodine postpartum during the breastfeeding period in order to reach the recommended total daily intake of 230–260 µg [4, 5, 8]. Iodine deficiency is associated with an increased rate of miscarriage and stillbirth and can have detrimental effects on the physical and mental development of the growing child [12 – 14]. Additional supplementation of iron, docosahexaenoic acid (DHA) and vitamin D, on the other hand, is only recommended in women with a medically diagnosed deficiency [4]. Despite these recommendations, many pregnant women and also their gynecologists remain unsure about what constitutes appropriate supplementation before, during, and after pregnancy. A cross-sectional study performed a few years ago showed that pregnant women in Germany do not take the recommended dietary supplements early or frequently enough, while often taking unnecessary supplements in excess or in high doses [15]. At this point it is unclear whether this situation can be influenced through targeted counselling. As part of the "Gesund leben in der Schwangerschaft" (GeliS; "Healthy living in pregnancy") study [16], the dietary supplements taken by participants before, during, and after pregnancy were recorded. Furthermore, it was investigated whether lifestyle counselling based on the recommendations of the "Healthy Start – Young Family Network" [17], offered during pregnancy in gynecology practices, would improve the supplementation behavior of women during and after their pregnancy when compared to a control group.

Methods

Design and setting of the GeliS study

The GeliS study is a multicenter, prospective, cluster-randomized, controlled open intervention study that was performed in five administrative districts of Bavaria (Oberbayern, Oberpfalz, Oberfranken, Mittelfranken and Unterfranken), a federal state in south-eastern Germany [16]. For each district, one intervention and one control region were chosen so that they had comparable birth rates and demographic parameters. In the intervention regions, specially trained staff in the medical practices, including medical assistants, midwives, and gynecologists, held lifestyle counselling sessions at gestational weeks 12–16, 16–20, and 30–34. An additional counselling session took place after birth (6–8 weeks postpartum) [16]. The primary aim of the study was to decrease the proportion of women who gained an excessive amount of weight during pregnancy [19], as defined by the criteria of the Institute of Medicine [18]. The study protocol was approved by the ethics committee of the Technical University of Munich and the study was registered in the ClinicalTrials.gov Protocol Registration System (NCT01958307).

Recruitment of participants

From 2013 to 2015, 2286 pregnant women from 71 gynecology practices were recruited for the GeliS study. The participants were enrolled in the study before 12 weeks of gestation if they were aged between 18 and 43, had a body mass index between 18.5 and 40.0 kg/m^2, sufficient German language skills, and had given their written informed consent. Exclusion criteria were multiple pregnancies or high-risk pregnancies, or severe illnesses that interfered with the adherence to the study protocol. Further causes for exclusion of study participants in the course of the intervention phase were miscarriage, severe pregnancy complications, abortion, or maternal death [16].

The GeliS lifestyle intervention

The counselling sessions encompassed the topics of a healthy diet and dietary supplementation during pregnancy and the breastfeeding period, physicial activity as well as appropriate weight gain during pregnancy. The participants in the intervention group (IG) were informed about the increased need for vitamins and mineral nutrients, as well as the importance of the micronutrients iodine and folic acid. Iron supplements were only to be taken in cases where there was a diagnosed deficiency. All contents of the lifestyle counselling were based on the recommendations of the network "Healthy Start – Young Family Network" [17] and were presented with the help of standardized presentation boards, teaching kits, and brochures. The women in the control group (CG) received routine medical examinations during pregnancy, along with a flyer and brochures with brief and general information on a healthy lifestyle during pregnancy [16].

Data collection of dietary supplementation and other covariates

Upon inclusion in the study, a questionnaire was used to record the anthropometric, demographic, and socioeconomic characteristics of the participants, such as age, height, pre-pregnancy weight, educational level, and parity. The participants' weight gain during pregnancy was calculated using the last weight measured prior to delivery and the first weight measured upon recruitment. During early pregnancy (< 12 weeks of gestation), late pregnancy (30–34 weeks of gestation), and at 6–8 weeks postpartum, the women were questioned on their dietary and physical behavior as well as their dietary supplementation with the help of a paper-based set of questionnaires. The questionnaire included a free-text field for entering the names and manufacturers of the products that were taken. The supplementation period was determined using the following response options:

- "only prior to pregnancy"
- "prior to pregnancy until … week of gestation"
- "from … week of gestation until … week of gestation"

Postpartum, the supplementation period was determined using the following response options:

- "from birth until … week postpartum" and
- "from … week until … week postpartum".

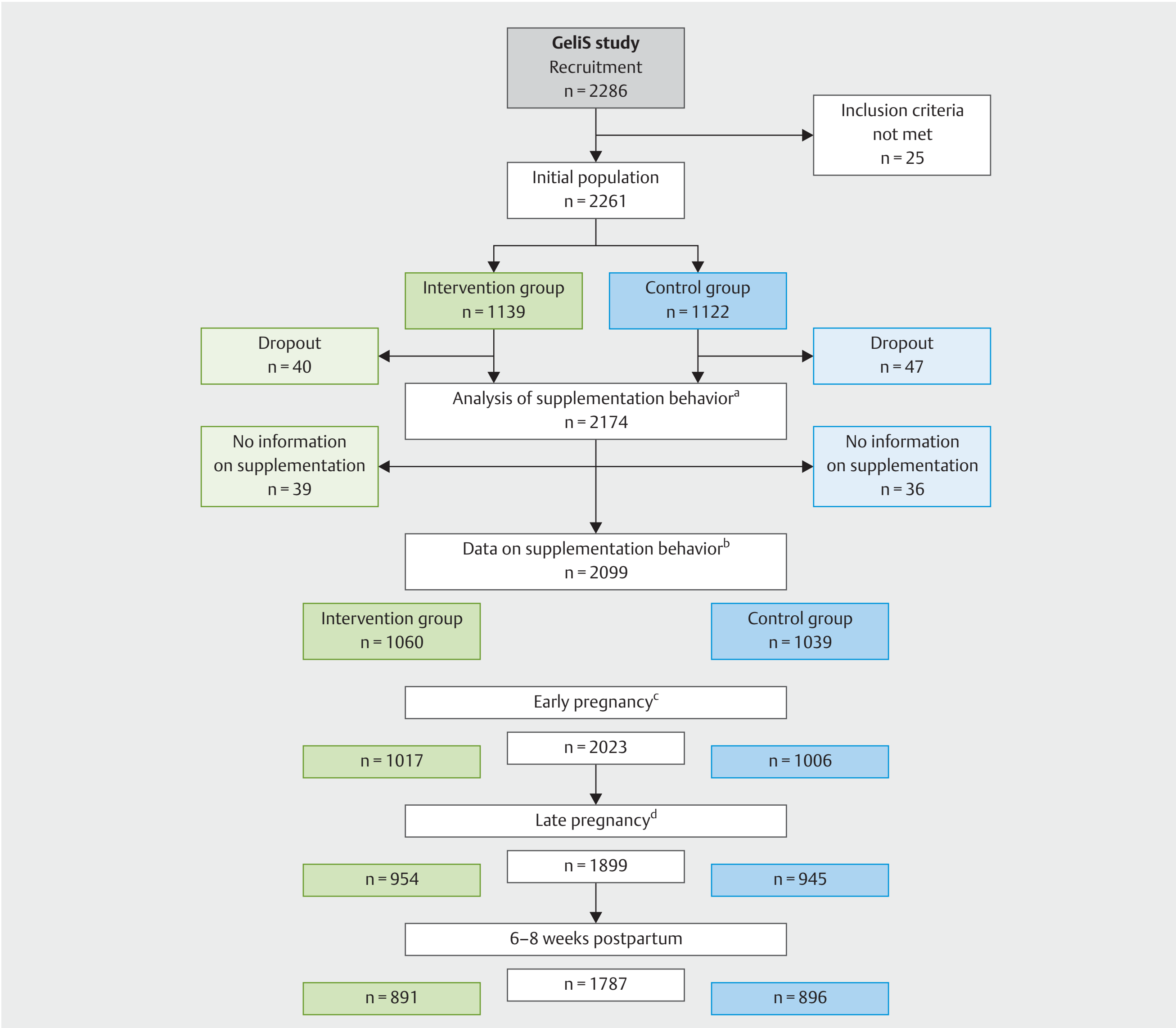
The frequency of supplement intake during and after pregnancy was specified using the following response options:

- "several times daily",
- "once daily",
- "every … days" and
- "weekly".

The information entered in the free-text field was taken into consideration for the analysis of supplement intake provided that the named products were supplements according to the German Food Supplements Regulation (NemV) of the Federal Ministry of Justice [20] and the Directive 2002/46/EC103 of the European Parliament and Council [21]. If prescription medication, pharmacy-only products, homeopathic products, or pharmaceuticals were named, these were excluded. With the help of the product names, the micronutrients contained in each product and the corresponding dosage instruction could be determined. To measure the daily intake volume of these nutrients, the quantity of micronutrients was calculated according to the dosage instruction and then multiplied by the intake frequency specified in the questionnaire.

Statistical analysis

In this analysis, all participants were included who had answered at least one of the three questionnaires on dietary supplements. Participants were excluded from individual analyses if the necessary information was missing. Differences between the IG and CG with regard to the intake of folic acid, iodine, and other micronutrients before, during, and after pregnancy were examined using generalized estimated equations taking into account the cluster-randomization of the study [22]. Using logistic regression models, the effect of the intervention on the intake of folic acid



▶ **Fig. 1** Flow chart. GeliS: "Gesund leben in der Schwangerschaft" (Healthy living in pregnancy). [a] Participants who were considered for inclusion in the supplementation behavior analysis. [b] Participants who gave information about their supplementation behavior during early and/or late pregnancy and/or 6–8 weeks postpartum. [c] < 12 weeks of gestation. [d] 30–34 weeks of gestation.

was examined for various subgroups. The intake of selected micronutrients was analysed independently of group assignment. For the calculation of the average quantity of nutrients taken daily (reported as median values), only those participants were taken into account who had specified product names and intake frequencies so that it was possible to determine the quantity of each micronutrient. Consequently, women who did not specify the information needed to determine the nutrient quantity were excluded from this calculation. As part of a cohort analysis, the potential influence of demographic and socioeconomic factors on the general intake of dietary supplements was examined using a logistic regression model. For this, the group assignment was included in the model as an additional adjustment factor. The statistical analysis of the data was carried out using IBM SPSS Statistics for Windows (Version 26.0 IBM Corp, Armonk, NY, USA). In all regression models, the women's pre-pregnancy BMI category, as well as age, parity, and educational level, were taken into account as adjustment factors. A p-value of < 0.05 was considered statistically significant. As this was an explorative analysis, there was no adjustment for multiple testing.

Results

Participants and their characteristics

In total, 2286 women were included in the GeliS study (▶ **Fig. 1**). After checking the inclusion and exclusion criteria, 25 women were subsequently excluded, so that 1139 women received the

▶ **Table 1** Characteristics of the study participants.

	Intervention group (n = 1060)	Control group (n = 1039)	Total (n = 2099)
Pre-pregnancy age (years)[a]	30.1 ± 4.3	30.3 ± 4.6	30.2 ± 4.5
Pre-pregnancy weight (kg)[a]	68.4 ± 13.1	67.9 ± 13.7	68.1 ± 13.4
Pre-pregnancy BMI (kg/m^2)[a]	24.4 ± 4.4	24.3 ± 4.6	24.3 ± 4.5
Pre-pregnancy BMI category, n (%)			
▪ BMI 18.5–24.9 kg/m^2	685/1060 (64.6 %)	687/1039 (66.1 %)	1372/2099 (65.4 %)
▪ BMI 25.0–29.9 kg/m^2	251/1060 (23.7 %)	225/1039 (21.7 %)	476/2099 (22.7 %)
▪ BMI 30.0–40.0 kg/m^2	124/1060 (11.7 %)	127/1039 (12.2 %)	251/2099 (12.0 %)
Gestational weight gain (kg)[a]	13.9 ± 5.3	14.0 ± 5.3	13.9 ± 5.3
Educational level, n (%)			
▪ General secondary school[b]	155/1059 (14.6 %)	173/1035 (16.7 %)	328/2094 (15.7 %)
▪ Intermediate secondary school[c]	455/1059 (43.0 %)	429/1035 (41.4 %)	884/2094 (42.2 %)
▪ High school[d]	449/1059 (42.4 %)	433/1035 (41.8 %)	882/2094 (42.1 %)
Country of birth, n (%)			
▪ Germany	931/1059 (87.9 %)	929/1036 (89.7 %)	1860/2095 (88.8 %)
▪ Other	128/1059 (12.1 %)	107/1036 (10.3 %)	235/2095 (11.2 %)
Living with their partner, n (%)	1021/1056 (96.7 %)	988/1036 (95.4 %)	2009/2092 (96.0 %)
Primiparous, n (%)	661/1060 (62.4 %)	556/1038 (53.6 %)	1217/2098 (58.0 %)

BMI: body mass index.
[a] mean value ± standard deviation. [b] General secondary school: General school, which is completed through year 9. [c] Intermediate secondary school: Vocational secondary school, which is completed through year 10. [d] High school: Academic high school, which is completed through year 12 or 13.

lifestyle counselling and 1122 women the routine prenatal care. Following exclusion of the women who dropped out of the study prematurely, there were still 2174 women left for evaluation of supplementation behavior. Since not all women were able to give information about their supplementation behavior on at least one of the three time points of data collection, there remained a total of 2099 participants (IG: n = 1060; CG: n = 1039) who provided data for analysis. Information was gathered from 2023 women in early pregnancy, 1899 women in late pregnancy, and 1787 women at 6–8 weeks postpartum (▶ **Fig. 1**).

On average, the women were 30.2 years old and had a BMI of 24.3 kg/m^2 (▶ **Table 1**). A third of all women were classified as overweight or obese. The average weight gain during pregnancy was 13.9 kg in the IG and 14.0 kg in the CG. 15.7 % of all women completed the general secondary school, while 42.2 % of the study participants attended the intermediate secondary school, and 42.1 % attended the high school. 88.8 % of the women specified Germany as their country of birth. The IG contained more primiparous women than did the CG (IG: 62.4 % vs. CG: 53.6 %).

Supplementation in the intervention and control groups

Dietary supplements were taken either before, during, or after pregnancy by 64.0 % of the women in the IG and 63.7 % of the women in the CG (▶ **Table 2**). Prior to pregnancy, this percentage was 34.6 % in the IG and 34.5 % in the CG, which increased to 54.5 % in the IG and 52.2 % in the CG during early pregnancy. In the course of the pregnancy until 6–8 weeks postpartum, this percentage decreased continually. In the postpartum phase, a larger proportion of women in the CG reported taking supplements (IG: 14.4 %; CG: 28.0 %). The difference in the rate of supplementation between the groups during the postpartum phase was statistically significant in the unadjusted model (data not shown). After taking the adjustment factors into account, however, this could not be validated (▶ **Table 2**).

Folic acid supplements were taken prior to conception by 31.3 % of women in the IG and 31.4 % in the CG. This proportion increased in the first trimester (IG: 51.8 %; CG: 48.9 %) and then decreased again throughout the remaining duration of the pregnancy. 27.3 % of women in the IG and 27.0 % in the CG took iodine prior to conception, while during pregnancy this increased to 50.2 % in the IG and 48.2 % in the CG (▶ **Table 2**). Prior to inclusion in the trial, there was no statistically significant difference between the two groups with regard to supplementation behavior. Even following the intervention, no statistical evidence of significant group differences was found for either general supplement intake or folic acid or iodine intake during and after pregnancy (▶ **Table 2**). Similarly, the analysis of iron, DHA, and vitamin D supplementation did not show any differences between the groups (Table **S1**).

Further analyses confirmed that the lifestyle intervention had a significant influence on dietary supplementation in certain subgroups (Table **S2**). The supplementation of folic acid by women in the IG with the highest level of education was significantly lower

▶ **Table 2** Supplementation of selected micronutrients in the intervention and control groups.

	Intervention group		Control group		Effect size (95% CI)[a]	p-value
	n	%	n	%		
Supplements in general						
Before/during/after pregnancy[b]	678/1060	64.0%	662/1039	63.7%	0.97 (0.70–1.33)	0.840
Prior to pregnancy	364/1052	34.6%	358/1039	34.5%	0.98 (0.85–1.12)	0.726
During pregnancy	627/1052	59.6%	600/1039	57.7%	1.02 (0.84–1.25)	0.835
▪ First trimester	573/1052	54.5%	542/1039	52.2%	1.07 (0.89–1.29)	0.483
▪ Second trimester	488/954	51.2%	486/945	51.4%	0.95 (0.70–1.28)	0.720
▪ Third trimester	437/954	45.8%	426/945	45.1%	0.97 (0.75–1.26)	0.819
Postpartum	128/891	14.4%	251/896	28.0%	0.28 (0.05–1.66)	0.160
Folic acid						
Prior to pregnancy	329/1052	31.3%	326/1039	31.4%	0.96 (0.87–1.06)	0.414
During pregnancy	569/1052	54.1%	540/1039	52.0%	1.07 (0.91–1.27)	0.416
▪ First trimester	545/1052	51.8%	508/1039	48.9%	1.10 (0.93–1.31)	0.279
▪ Second trimester	427/954	44.8%	428/945	45.3%	0.94 (0.73–1.20)	0.603
▪ Third trimester	340/954	35.6%	345/945	36.5%	0.93 (0.73–1.18)	0.560
Postpartum	105/891	11.8%	197/896	22.0%	0.36 (0.07–1.82)	0.213
Iodine						
Prior to pregnancy	287/1052	27.3%	281/1039	27.0%	1.03 (1.00–1.07)	0.070
During pregnancy	528/1052	50.2%	501/1039	48.2%	1.05 (0.86–1.27)	0.660
▪ First trimester	503/1052	47.8%	465/1039	44.8%	1.11 (0.90–1.36)	0.352
▪ Second trimester	398/954	41.7%	396/945	41.9%	0.94 (0.72–1.24)	0.682
▪ Third trimester	317/954	33.2%	317/945	33.5%	0.95 (0.75–1.21)	0.665
Postpartum	108/891	12.1%	215/896	24.0%	0.29 (0.05–1.57)	0.151

CI: confidence interval.
[a] Logistic regression model adjusted for pre-pregnancy BMI category, age, educational level, and parity.
[b] This included participants who took supplements before and/or during and/or after pregnancy.

compared to those in the CG during the second trimester ($p = 0.017$) and third trimester ($p = 0.017$). Compared to the CG, a larger proportion of women in the IG with an intermediate level of education took folic acid supplements during their pregnancy ($p < 0.001$). In the group with the lowest level of education, significantly more women took folic acid supplements during the third trimester in the IG ($p = 0.048$) compared to the CG. Significant subgroup differences were also found with regard to BMI category and age. For example, a higher percentage of women with obesity (second trimester: $p < 0.001$; third trimester: $p = 0.004$) and women aged 18–25 years (second trimester: $p = 0.004$; third trimester: $p = 0.014$) in the IG took folic acid supplements during their pregnancy compared to the CG. The analysis of the iodine supplementation in these subgroups revealed similar tendencies (data not shown).

Further dietary supplementation and dosage

▶ **Table 3** presents the intake of additional micronutrients independent of the participants' group assignment. In total, within the context of pregnancy, 467 different dietary supplements were taken by the participants, comprising a total of 24 different micronutrients. More than one in five women reported taking an iron supplement (21.8%) or DHA (23.0%) during pregnancy. The proportion of women taking iron supplements increased during the course of the pregnancy. Meanwhile, the proportion of women taking DHA remained relatively stable (▶ **Table 3**). Vitamin D was supplemented by 28.6% of participants prior to pregnancy, 46.6% during early pregnancy, and 33.1% during late pregnancy (▶ **Table 3**). Magnesium was supplemented by 23.7% of pregnant women in the second and third trimester (▶ **Table 3**). Furthermore, 50.5% of the participants reported taking vitamin B_{12} supplements during their pregnancy (▶ **Table 3**).

In further analyses, the mean quantity of selected micronutrients taken daily was calculated. The women who took folic acid supplements and specified information that allowed for calculation of the daily intake consumed on average 800 µg folic acid daily, both prior to pregnancy as well as during the first trimester (▶ **Table 4**). This dose was reduced to 400 µg/day from the second trimester onwards, including the postpartum period. The median iodine intake remained constant at 150 µg daily. Where it was possible to calculate the amount of iron consumed, participants took an average of 15 mg/day, up to and including the second tri-

▶ Table 3 Supplementation of selected micronutrients in the GeliS cohort.

	Prior to pregnancy		During pregnancy		Postpartum	
	n	%	n	%	n	%
Iron	110/2091	**5.3%**	455/2091	**21.8%**	84/1787	**4.7%**
			T1	12.0%		
			T2	17.4%		
			T3	19.7%		
DHA	135/2091	**6.5%**	481/2091	**23.0%**	140/1787	**7.8%**
			T1	17.7%		
			T2	21.5%		
			T3	18.7%		
Vitamin D	597/2091	**28.6%**	1032/2091	**49.4%**	283/1787	**15.8%**
			T1	46.6%		
			T2	41.1%		
			T3	33.1%		
Magnesium	130/2091	**6.2%**	529/2091	**25.3%**	51/1787	**2.9%**
			T1	13.5%		
			T2	23.7%		
			T3	23.7%		
Vitamin B_{12}	614/2091	**29.4%**	1055/2091	**50.5%**	285/1787	**15.9%**
			T1	47.5%		
			T2	42.4%		
			T3	33.9%		

Figures as percentages.
DHA: docosahexaenoic acid; T1: first trimester; T2: second trimester; T3: third trimester.

mester. The daily iron intake through supplementation reached a maximum in the third trimester, at 37.0 mg/day. The dose of magnesium was steadily increased from the phase prior to pregnancy until the end of pregnancy (▶ **Table 4**). In contrast, the dose of vitamin B_{12} was at its highest prior to pregnancy and in the first trimester (9.0 µg).

Factors influencing the intake of supplements

▶ **Table 5** gives an overview of the demographic and socioeconomic factors that were associated with dietary supplementation. There was a significant positive association between the educational level and the intake of supplements ($p < 0.001$). At all times, the rate of supplementation was highest among women with the highest level of education (Table **S3**). There was no significant association between the intake of supplements and BMI category ($p = 0.407$); however, there was a significant association with the participants' age ($p < 0.001$). Women over the age of 26 years were more likely to take supplements than women aged 18–25 years (26–35 years: $p < 0.001$; 36–43 years: $p = 0.012$). The difference observed between these age groups was statistically significant in the period prior to pregnancy and during the first trimester (Table **S3**). Furthermore, there was a significant association between a higher supplementation rate and primiparity ($p < 0.001$), non-smoker status ($p < 0.001$), or a vegetarian diet ($p = 0.037$). During the second and third trimester, in particular, the probability of supplementing micronutrients was higher among vegetarians when compared with non-vegetarians (Table **S4**).

Discussion

In the present study, the supplementation behavior of a large cohort of pregnant women was reviewed, in particular to examine the way in which the GeliS lifestyle counselling would influence the supplementation behavior of women during and after pregnancy. The results did not show any significant changes in supplementation behavior as a result of the intervention. In both groups, folic acid and iodine supplements were only taken by about 50% of women during pregnancy. On the other hand, other micronutrients were often supplemented, at times in high doses, even though this was not recommended. This means that the recommendations of the nationwide network "Healthy Start – Young Family Network" [4] were only partially followed.

According to these recommendations, the timely supplementation of folic acid and iodine is particularly important. Because the closure of the neural tube occurs between day 21 and day 26 after conception, preconceptional supplementation with 400–800 µg of folic acid (depending on when the supplementation

▶ **Table 4** Quantities of supplemented micronutrients.

	Prior to pregnancy		During pregnancy						Postpartum	
			First trimester		Second trimester		Third trimester			
	n[a]	median	n[a]	median	n[a]	median	n[a]	median	n[a]	median
Folic acid (µg/d)	540/655	800.0	917/1053	800.0	785/855	400.0	634/685	400.0	275/302	400.0
Iodine (µg/d)	483/568	150.0	865/968	150.0	749/794	150.0	601/634	150.0	286/323	150.0
Iron (mg/d)	90/110	15.0	199/251	15.0	303/331	15.0	335/374	37.0	74/84	15.0
DHA (mg/d)	105/135	100.0	302/370	200.0	383/408	200.0	334/355	200.0	127/140	200.0
Vitamin D (µg/d)	509/597	20.0	865/974	20.0	728/780	20.0	586/628	20.0	263/283	20.0
Magnesium (mg/d)	87/130	150.0	213/283	180.0	381/451	245.0	374/450	266.7	46/51	94.0
Vitamin B_{12} (µg/d)	526/614	9.0	890/944	9.0	763/805	4.0	614/644	3.5	266/285	3.5

d: day; DHA: docosahexaenoic acid.
[a] This included participants who specified product names and intake frequency that allowed for calculation of the consumed amount of each micronutrient.

▶ **Table 5** Factors influencing the intake of supplements.

	Before/during/after pregnancy[a]			
	n	%	Effect size (95 % CI)	p-value
Educational level[b]				< 0.001
▪ General secondary school	151/328	46.0 %	Reference	
▪ Intermediate secondary school	524/884	59.3 %	1.58 (1.33–1.87)	< 0.001
▪ High school	662/882	75.1 %	3.00 (2.40–3.73)	< 0.001
BMI category[c]				0.407
▪ Normal weight	908/1372	66.2 %	Reference	
▪ Overweight	285/476	59.9 %	0.87 (0.70–1.09)	0.209
▪ Obesity	147/251	58.6 %	0.89 (0.72–1.08)	0.217
Age[d]				< 0.001
▪ 18–25 years	149/298	50.0 %	Reference	
▪ 26–35 years	1023/1544	66.3 %	1.66 (1.31–2.10)	< 0.001
▪ 36–43 years	165/255	65.1 %	1.62 (1.11–2.36)	0.012
Parity[e]				< 0.001
▪ Multiparity	537/881	61.0 %	Reference	
▪ Primiparity	803/1217	66.0 %	1.26 (1.12–1.41)	0.001
Smoking status[f]				< 0.001
▪ Non-smoker	1097/1568	70.0 %	Reference	
▪ Smoker	85/213	39.9 %	0.40 (0.34–0.47)	< 0.001
Vegetarian diet[f]				0.037
▪ No	1217/1852	65.7 %	Reference	
▪ Yes	80/111	72.1 %	1.24 (1.01–1.52)	0.037

CI: confidence interval; BMI: body mass index.
[a] This included participants who took supplements before and/or during and/or after pregnancy.
[a] Binary logistic regression model adjusted for group assignment, pre-pregnancy BMI category, age, parity.
[c] Binary logistic regression model adjusted for group assignment, educational level, age, parity.
[d] Binary logistic regression model adjusted for group assignment, educational level, pre-pregnancy BMI category, parity.
[e] Binary logistic regression model adjusted for group assignment, educational level, pre-pregnancy BMI category, age.
[f] Binary logistic regression model adjusted for group assignment, educational level, pre-pregnancy BMI category, age, parity.

was begun) is essential in order to lower the risk of neural tube defects and other deformities [4, 12, 23, 24]. Our analysis showed that only a third of the women took folic acid prior to conception. Three cross-sectional studies carried out in Germany in 2009 [15], 2015 [25], and 2018/19 [26] reported similarly low rates of folic acid supplementation, at 33.7%, 25%, and 45.4% respectively. A few years ago, a comparative, population-based study comparing data from 19 European countries, including Germany, showed that providing general recommendations on folic acid supplementation did not have a recognizable benefit. Furthermore, the incidence of neural tube defects did not decrease in the period from 1991 to 2011 [27]. This knowledge has recently led New Zealand and Great Britain to mandate an obligatory enrichment of flour with folic acid, following the lead of several other countries [28]. Considering the situation in Germany, a similar step should be discussed here.

A moderate iodine deficiency is widespread among the German population [29, 30]. In view of the increased requirement during pregnancy and the breastfeeding period, the iodine supplementation rate reported above of merely 50% is also unsatisfactory. Similarly, in a nationwide cross-sectional study [26] that retrospectively collected data on the intake of supplements during pregnancy, only 50.1% of the 966 women surveyed reported taking iodine supplements. In our analysis it was also noteworthy that the rate of iodine supplementation decreased significantly over the course of the pregnancy, falling to just 12–24% at 6–8 weeks postpartum, even though supplementation is still recommended during this period as the increased need for iodine remains relevant during late pregnancy and breastfeeding [4, 5]. According to the results of the DEGS1 study, the median quantity of iodine consumed by women of childbearing age from 2008 to 2011 amounted to about 125 µg/day; this means it lay significantly below the intake reference value for adult women of 200 µg/day, and even further below the recommended intake for pregnant women of 230 µg/day [8, 30]. Due to the fact that an iodine deficiency significantly compromises a child's psychomotor development, the supply of iodine should be increased during these critical phases [31].

Almost one in four women took a DHA supplement of 200 mg per day. This is equivalent to the daily minimum intake as stated in the D-A-CH-reference values for the nutrition of pregnant and breastfeeding women [8]. Beyond that, international professional societies recommend DHA supplementation in women when pregnant and breastfeeding [32]. Looking at the currently available data, however, the benefit of general DHA supplementation in all pregnant women has not yet been definitively proven [33]; accordingly, in Germany DHA supplementation is mainly recommended to women who do not consume fish, especially oily fish [4].

Approximately 20% of participants consumed iron supplements in varying doses. While there are no large-scale, representative data on the prevalence of iron deficiency anemia during pregnancy specifically for the German-speaking region, it is estimated that 28–85% of pregnant women throughout Europe have an iron deficiency [34]. The prevalence of diagnosed iron deficiency anemia among pregnant women in Europe is approximately 9% [35]. In these cases, supplementation with 30–40 mg/day is recommended [35, 36]. In principle, iron supplementation in the case of a medically diagnosed deficiency is recommended rather than an overarching general supplementation [4]. The degree to which the supplementation in this cohort occurred as a result of advice from a physician is unclear and was not recorded.

Vitamin B_{12} and D supplements were taken by approximately half of the participants over the course of their pregnancy. Evidence for the general consumption of vitamin D during pregnancy is as yet insufficient [37, 38]. Supplementation is only recommended in women with low levels of sun exposure, darker skin types, or a diagnosed deficiency [4]. The median intake dose of 20 µg/day in our analysis is in line with the intake recommendations of the German Nutrition Society for cases of people in the general population who lack endogenic synthesis [39]. The degree to which this applied to the participants could not be determined within the scope of this study. The need for vitamin B_{12} is only slightly increased during pregnancy [8] and can usually be met with a well-balanced mixed diet; usually, supplementation is not necessary or recommended. For pregnant vegetarians or vegans, on the other hand, vitamin B_{12} is considered a critical nutrient [4]. If consumption of animal products is largely or completely avoided, a permanent supplementation of vitamin B_{12} is advisable [40]. Only 5.3% of GeliS participants reported following a vegetarian diet (data not shown), so that it can be assumed that vitamin B_{12} was often supplemented without medical indication.

Many micronutrients are consumed as combination products. Apart from folic acid and iodine, there is no scientific evidence that supports the general consumption of other micronutrients.

Our results suggest that the general opinion among pregnant women and in their social environment is that the average diet does not ensure a sufficient supply of micronutrients, and thereby a broad supplementation of nutrients is necessary during pregnancy. However, this does not match the current scientific evidence. Clearly, there is a need to provide pregnant women and their gynecologists with evidence-based information in order to avoid unnecessary and excessive supplementation. It should also be mentioned that general supplementation, at times with excessively high doses of certain nutrients, may also pose a health risk for the mother and child [41].

In this analysis it was shown that a higher educational level and a advanced age were associated with a higher rate of supplementation. This correlates with trends observed in other studies [7, 42 – 44]. Primiparous women showed higher rates of folic acid supplementation than multiparous women (data not shown). Pregnant women following a vegetarian or vegan diet showed higher supplementation rates of a variety of nutrients, including vitamin B_{12}, especially in the second and third trimester (data not shown). According to the current consensus, an ovo-lacto-vegetarian diet is not associated with any additional risks during pregnancy as long as vitamin B_{12} is supplemented in addition to folic acid and iodine. Considering that vegetarian and vegan diets are becoming increasingly popular among young women [45], targeted nutritional counseling is needed in order to better take into account individual lifestyles and ensure adequate nutrient supply.

This study has certain limitations. For example, the data presented in this paper was collected between 2013 and 2015. The information provided on the intake of dietary supplements was collected retrospectively using a non-validated questionnaire. Therefore, memory gaps or an underestimation of the actual consumption cannot be ruled out. These results are not representative for the general German population, as they were collected from a cohort from one federal state, participants often had a high level of education, and pregnant women with migrant backgrounds were excluded if there were language barriers. The strength of this analysis, on the other hand, is that it offers a detailed insight into the supplementation behavior of a large sample, and the supplement intake was recorded several times at defined timepoints. This allowed for the portrayal of the time course of supplement intake before, during, and after pregnancy. For the postpartum period in particular there is a lack of data concerning dietary supplementation. The results showed that more than half of the participants stopped taking supplements postpartum, which fails to meet the ongoing increased requirement during the breastfeeding period.

Conclusion

The results shown here provide a clear indication that the supplementation of micronutrients before, during, and after pregnancy is not in accordance with the current recommendations. The supplementation rates of folic acid and iodine were clearly too low, and for folic acid not timely, as the intake was often initiated too late. On the other hand, many micronutrients were taken without any clear need for additional supplementation. The recommendations on adequate supplementation provided to participants in the IG were, however, not shown to be effective. Clearly, there is a need for more intensive education within the context of the gynecological care of young women. To achieve a significant improvement in supplementation behavior, this education should ideally be provided prior to conception to women intending to become pregnant. Gynecology practices and midwives, in particular, are called on in this context. If necessary, a consultation with a qualified nutritionist should be offered.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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