

Discrepancy Between Knowledge and Practice in Folic Acid Supplementation for NTD Prevention: A Mixed-Methods Study of Chinese Women

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1 **Title page:**

2 **Title:** Discrepancy Between Knowledge and Practice in Folic Acid Supplementation for NTD
3 Prevention: A Mixed-Methods Study of Chinese Women

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21 **Abstract**

22 **Background:** Neural tube defects (NTDs) remain a major preventable cause of congenital
23 disability worldwide. Existing evidence suggests a persistent gap between awareness and actual
24 supplementation behaviors among women of childbearing age.

25 **Aims:** To assess folic acid-related knowledge and supplementation behaviors among Chinese
26 women of childbearing age and to explore the knowledge–practice gap .

27 **Methods:** A mixed-methods study was conducted from June to September 2024. Quantitatively, a
28 self-designed questionnaire was administered to 5,741 women of childbearing age (aged 18–49
29 years) in mainland China. Outcomes included folic acid-related knowledge and supplementation
30 behaviors. Logistic regression was used to examine associations between knowledge and
31 behaviors. Qualitatively, semi-structured in-depth interviews based on the Health Belief Model
32 were conducted with 18 pregnant women attending an obstetric clinic. Data were analyzed using
33 directed content analysis. Mixed-methods results were jointly displayed.

34 **Results:** Among participants, 95.6% knew that folic acid prevents NTDs, but only 62.6% knew
35 the correct timing and 51.4% knew the recommended daily dose. Among the 4,470 women with
36 pregnancy or pregnancy-planning experience, 86.3% had obtained folic acid, 83.0% had taken it,
37 but only 28.7% adhered to the full regimen. Knowledge score was significantly associated with
38 adherence (OR = 1.624, 95% CI: 1.552–1.699). Qualitative findings revealed five major barriers:
39 insufficient perceived susceptibility, insufficient perceived severity of NTDs, perceived low
40 benefits of supplementation, perceived obstacles, and inadequate action cues. The mixed-methods

integration highlighted that knowledge deficits, exacerbated by generic health information and brief provider advice, explained the low adherence.

Conclusion: Although awareness of folic acid's role in NTD prevention is high, correct and sustained supplementation remains poor among Chinese women of childbearing age. The knowledge-behavior gap is driven by multiple cognitive and information-related barriers. Targeted, individualized, and theory-based health education strategies are urgently needed to improve adherence.

Keywords: folic acid; neural tube defects; women of childbearing age; medication adherence; health belief model; mixed-methods research

Background

NTDs are a group of severe congenital malformations of the central nervous system, primarily resulting from incomplete closure of the neural tube during early embryonic development. These defects include anencephaly, spina bifida, and encephalocele^[1]. Globally, the incidence of NTDs is approximately 18.6/10,000 live births, corresponding to an estimated 260,100 cases annually. More than half of affected pregnancies are terminated due to fetal anomalies or stillbirth, and among live-born infants with NTDs, approximately 75% die before the age of five^[2].

In the 1980s, a multicenter, randomized, double-blind trial conducted across seven countries compared supplementation with 4 mg of folic acid to multivitamins, demonstrating that folic acid effectively prevents the recurrence of NTDs^[3]. Currently, folic acid supplementation for the

prevention of NTDs has been incorporated into national health policies worldwide. Since 1990, more than 70 countries, including the United States, Canada, Chile, and South Africa, have implemented mandatory folic acid fortification of staple foods such as flour, resulting in a significant reduction in NTD incidence^[4]. Since 2009, China has incorporated the “Folic Acid Supplementation Program for the Prevention of Neural Tube Defects” into its National Basic Public Health Service Program, providing free folic acid to rural women planning pregnancy nationwide.

Regarding knowledge related to folic acid supplementation, most studies indicate that women of childbearing age have a relatively high basic awareness rate of folic acid, yet significant disparities exist in their mastery of specific knowledge about folic acid. For instance, multiple studies have shown that over 60% of respondents reported having heard of folic acid^[5-9]. However, only 23.7% of women in South Korea had a clear understanding of the role of folic acid in preventing neural tube defects and the correct timing for supplementation^[6]. In contrast, a study covering four cities in China reported that up to 65.9% of participants were aware of the preventive role of folic acid and the correct time for its intake^[5], suggesting that socioeconomic status and access to health education resources may influence knowledge acquisition.

With respect to folic acid supplementation behaviors, the rate of periconceptional supplementation is suboptimal worldwide. A meta-analysis reported the prevalence of periconceptional folic acid supplementation across 34 countries: 32%–51% in North America, 9%–78% in Europe, 21%–46% in Asia, 4%–34% in the Middle East, 32%–39% in Australia/New Zealand, 0% in Africa^[10]. Furthermore, a study conducted in six Chinese provinces with high neural tube defect prevalence found that the folic acid supplementation rate among women was

only 12%, and the rate of strict adherence to the recommended dosage was even lower, at just 8%^[11].

In summary, as a major global public health issue, NTDs exhibit significant regional disparities in their incidence, with a particularly high disease burden in low-income countries. Although China has achieved a marked reduction in NTD incidence through folic acid fortification policies, its large population base continues to make NTDs a priority in birth defect prevention and control. As a core strategy for the primary prevention of NTDs, the effectiveness of folic acid supplementation has been confirmed by multiple randomized controlled trials and long-term cohort studies worldwide. Nevertheless, the rate of standardized periconceptional folic acid supplementation remains generally below expected targets globally. This study aims to quantify the discrepancy between knowledge and practice regarding periconceptional folic acid supplementation among Chinese women of childbearing age, and to explore the underlying cognitive and informational barriers through a mixed-methods design.

Identification of Problems

This study employed a mixed-methods design integrating both quantitative and qualitative approaches^[12]. Firstly, the current status of folic acid intake and knowledge level of women of childbearing age were quantified through a questionnaire survey. Based on the survey findings, clinically meaningful issues related to folic acid were identified. Subsequently, guided by the Health Belief Model, qualitative interviews were conducted to further explore participants' perceptions of neural tube defect (NTD) risks, cognitive barriers to supplementation, and related behavioral beliefs during the process of folic acid intake, aimed to identify the underlying factors influencing intake behaviors. Finally, the quantitative and qualitative findings were integrated to

comprehensively elucidate the existing problems in folic acid intake for the prevention of fetal NTD among women of childbearing age. This provides foundational data support for subsequent evidence synthesis to ensure that future research is aligned with the actual needs of the target population.

This report is in accordance with the Good Reporting of A Mixed Methods Study (GRAMMS) guidelines^[13].

1.Methods

1.1 Quantitative Study: Participants and Methods

From June to July 2024, a convenience sampling method was adopted to survey women of childbearing age in mainland China. The inclusion criteria were as follows: (1) aged 18–49 years; (2) capable of completing the questionnaire; and (3) willing to participate in this study.

This study was conducted based on the “Awareness Rate of Birth Defect Prevention Knowledge among the Reproductive Population” project. The survey instrument was a self-developed questionnaire, which included general demographic information and questions related to core knowledge and behaviors concerning birth defect prevention. (1) General demographic information: including age, occupation, annual income, and educational level; (2) Knowledge of birth defect prevention: based on the “Core Information on Health Education for Birth Defect Prevention” issued by the National Health Commission^[14], combined with relevant literature^[15-19]. This section consisted of 29 items (25 single-choice questions and 4 fill-in-the-blank questions), with one point awarded for each correct answer. Among them, 5 items were related to folic acid knowledge; (3) Birth defect preventive behaviors: designed based on relevant literature^[20, 21],

including 10 single-choice questions and 1 fill-in-the-blank question, covering premarital examination, pregnancy planning, preconception and prenatal examinations, and folic acid supplementation. Six items were related to folic acid supplementation behaviors; (4) Validation questions: used to identify valid responses.

The questionnaire was reviewed by a panel of experts in obstetrics and public health to ensure content validity, and a pilot test was conducted with 50 women to assess clarity and comprehensibility.

An online survey was conducted. After the questionnaire was designed, it was distributed via the Wenjuanxing platform, with each WeChat account restricted to one submission to reduce duplicate responses. The minimum sample size was determined based on the lowest reported awareness rate of birth defects-related knowledge. Literature review indicated that the awareness rate for the least known items ranged from 28.7% to 31.5%; therefore, a rate of 30% ($\pi = 0.3$) was adopted for calculation. A relative error of no more than 15% was specified, yielding an absolute error of $\delta = 15\% \times 30\% = 4.5\%$. A 95% confidence level was chosen, corresponding to a standard normal deviate of $\mu_0 = 1.96$. A stratified sampling design was employed, with strata defined by economic region (eastern, central, and western) and further by urban/rural residence, resulting in 6 strata. A design effect (deff) of 2 was assumed. The sample size per stratum was calculated using the formula: $n = \frac{\text{deff} \mu_0^2 \cdot \pi(1-\pi)}{\delta^2}$

Substituting the values gave: $n = 2 \frac{1.96^2 \times 0.3 \times 0.7}{0.045^2} \approx 797$

Thus, the total required sample size was $797 \times 6 = 4782$. Accounting for an anticipated 20% invalid or incomplete responses, the final minimum sample size was set at $4782/0.8 = 5978$

participants. A total of 7,141 questionnaires were collected. After excluding 237 responses that did not meet the age criteria, 4 that did not meet the regional criteria, and 1,159 invalid responses based on validation questions, 5,741 valid questionnaires were included, with an effective response rate of 80.39%. This effective sample size (5,741) exceeds the required minimum sample size of 4,782 (before accounting for anticipated invalid responses) and is only slightly below the adjusted target of 5,978, indicating that the sample size is sufficient for the planned analyses. Among the valid respondents, 4,470 respondents had pregnancy experience or pregnancy plans.

Data were analyzed using SPSS version 26.0. The main analytical methods were as follows: (1) Categorical variables (e.g., gender, educational level) were described using frequencies (n) and percentages (%); (2) Multivariate analysis: logistic regression analysis was conducted to examine factors influencing folic acid intake behavior, and odds ratio (OR) with 95% confidence interval (CI) were calculated. All statistical tests were two-sided, with a significance level set at $\alpha = 0.05$.

1.2 Qualitative Study: Participants and Methods

A purposive sampling method was adopted. As the aim of the interviews based on the Health Belief Model^[22], was to explore the health belief structure of women of childbearing age during the process of folic acid intake—including perceived susceptibility to NTDs, perceived benefits and barriers of folic acid supplementation, behavioral motivation, and self-efficacy—participants were required to have experience with folic acid intake to provide data sources in line with the research purpose. Participants were recruited from pregnant women undergoing fetal monitoring in the obstetrics outpatient department of a tertiary hospital between August and September 2024. The inclusion criteria were: (1) aged 18–49 years; (2) able to communicate effectively; and (3)

normal pregnancy without complications. The exclusion criteria were: (1) healthcare professionals; and (2) individuals with cognitive impairment or psychiatric disorders that would prevent cooperation. The sample size was determined based on data saturation.

A semi-structured interview guide was developed based on the research objectives and the five core dimensions of the Health Belief Model^[22], including: (1) perceived susceptibility (an individual's perception of the likelihood of experiencing a health problem or developing a particular disease); (2) perceived severity (an individual's perception of the seriousness of the consequences resulting from unhealthy behaviors or a given disease); (3) perceived benefits (an individual's subjective evaluation of the benefits gained from adopting health-related behaviors); (4) perceived barriers (an individual's subjective assessment of the obstacles to adopting health-related behaviors); (5) cues to action (categorized facilitating or triggering factors that promote an individual's engagement in health-related behaviors). An analytical framework for folic acid intake behavior was thus established. Two pilot interviews were conducted prior to formal interviews, and the guide was revised accordingly. The interviews focused on timing, dosage, and regularity of folic acid intake; knowledge of its role in preventing NTDs; difficulties encountered during intake; and reviews of online health education and medical counseling. Factors influencing folic acid intake behavior were also focused.

Data were collected through face-to-face, semi-structured, in-depth interviews. Before the interview, the researcher explained the study purpose, methods, and procedures, and obtained verbal informed consent. With participants' permission, interviews were audio-recorded. The interviewer maintained a positive, attentive and accepting attitude, listen carefully and try not to interrupt the interviewee, using summarization and probing techniques to clarify responses and

observe non-verbal cues. Each interview lasted 10–15 minutes. Field notes and reflective logs were completed after each interview.

Within 24 hours after each interview, recordings were transcribed verbatim. Directed content analysis^[23] was performed by two researchers independently. Transcripts were repeatedly reviewed and coded line-by-line. NVivo 11.0 software was used for open coding, grouping similar codes into categories, generating themes and subthemes, and extracting representative examples from the original data. Based on the Health Belief Model, a directed thematic analysis approach was adopted. Based on the codes, a list of 30 initial themes was generated. After discussion of the initial themes by all authors, they were condensed into five main themes. Thematic saturation was used as the criterion, meaning that data were considered saturated when no new themes or codes emerged across three consecutive interviews. Data saturation was reached after 18 interviews; two additional interviews yielded no new information and were not included in the analysis.

1.3 Integration of Quantitative and Qualitative Methods

This study employed an explanatory sequential mixed methods design, with integration planned and implemented at multiple stages of the research process.

Design-level integration. The study was conducted in two sequential phases. Phase 1 (quantitative) quantified folic acid-related knowledge and supplementation behaviors in a large sample of Chinese women of childbearing age and established statistical associations between knowledge scores and adherence. Phase 2 (qualitative) was built directly on the core quantitative finding—a marked discrepancy between high awareness and low adherence—to explore why this knowledge–practice gap exists. Thus, the quantitative results defined the research question for the

qualitative phase, while the qualitative findings were intended to explain and contextualize the numerical patterns.

Methods-level connecting. The results of the quantitative analysis informed the qualitative data collection in two ways. First, because the survey identified “correct timing” and “recommended dosage” as the weakest knowledge items, the semi-structured interview guide was refined to probe more deeply into perceived barriers and cues to action related specifically to these aspects. Second, the purposive sampling strategy for the qualitative phase deliberately recruited pregnant women who reported having taken folic acid but demonstrated suboptimal adherence in terms of timing or frequency, thereby ensuring that the interview data could maximally illuminate the mechanisms underlying the observed gap.

Results-level integration and joint display. Integration at the interpretation stage was achieved through a joint display, as presented in Fig. 1 (Section 2.3). In this display, the key quantitative finding (the negative association between knowledge deficits and adherence) is placed alongside the main qualitative themes (insufficient personalized online recommendations, the need to filter online information, and inadequate provider-delivered health education). This side-by-side presentation makes visible how the cognitive and informational barriers identified in the qualitative interviews are linked to the statistically estimated impact of knowledge on behavior. In addition, the six core questions distilled from the interviews (Table 7) concretize the specific knowledge gaps that underpin the gap between 95.6% awareness and only 28.7% full adherence. Together, the quantitative and qualitative strands provide a comprehensive, multi-dimensional explanation of the discrepancy between knowledge and practice in folic acid supplementation.

1.4 Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Peking University Biomedical Ethics Committee (Approval No.: IRB00001052-24088). For the quantitative survey, electronic informed consent was obtained from all participants prior to their access to the online questionnaire. Participants were informed of the voluntary nature of participation, the anonymity of their responses, and their right to withdraw at any time without penalty. For the qualitative component, verbal informed consent was obtained from all participants prior to the commencement of audio-recorded interviews. All interview recordings and transcripts were de-identified to ensure participant confidentiality.

2 Results

2.1 Quantitative study

2.1.1 Basic Characteristics of Participants

A total of 5,741 valid questionnaires were collected in this survey, covering the eastern, northeastern, central, and western regions of China. The respondents were predominantly aged 25–49 years (83.43%). Household registration types were relatively balanced, while the majority of participants resided in urban areas (75.13%). In addition, most respondents were non-migrants (86.46%), a high proportion were married (76.67%), and over 70% had at least one child. The general characteristics of the respondents are presented in Table 1.

2.1.2 Awareness of folic acid-related knowledge

Table 2 presents the awareness of folic acid-related knowledge among women of childbearing age. The results showed that 95.6% of the respondents were aware that

254 periconceptional folic acid supplementation can prevent neural tube defects, 94.4% were aware of
 255 foods rich in natural folate, and 89.0% were aware of the policy of free folic acid distribution.
 256 However, only 62.6% of the respondents were aware of the appropriate timing for folic acid
 257 supplementation, and merely 51.4% knew the recommended intake of folic acid.

Table2 Awareness Rate of Folic Acid-related Knowledge among Women of childbearing
 age (n=5741)

Problems	Awareness(%)
Periconceptional folic acid supplementation can prevent neural tube defects.	5490(95.6)
Foods rich in natural folate	5422(94.4)
The appropriate timing for folic acid supplementation	3594(62.6)
The recommended intake of folic acid	2949(51.4)
The policy of free folic acid distribution (n=4470, N/%)*	3978(89.0)

258 *As this question is designed for women of childbearing age who have been pregnant before or have
 259 plans to conceive, the number of entries is 4,470

260 2.1.3 Folic acid-related behaviors

261 Table 3 presents the folic acid-related behaviors among women of childbearing age who had
 262 previous pregnancy experience or were planning pregnancy (n=4470). The proportion of
 263 respondents who obtained folic acid (either through free collection or purchase) was 86.3%,
 264 among whom 83.0% reported taking folic acid. However, the proportion of those who initiated

265 supplementation 3 months before pregnancy and continued until 3 months after pregnancy
266 decreased to 49.8%. Further analysis showed that 44.7% adhered to daily folic acid intake until 3
267 months after pregnancy. Only 28.7% of individuals are able to both adhere to daily
268 supplementation from three months preconception to three months postconception and take the
269 correct dosage. These findings suggest that although most women of childbearing age have a
270 certain level of awareness of the importance of birth defect prevention, there remains considerable
271 room for improvement in terms of the timely initiation of folic acid supplementation, daily
272 adherence, and compliance with the recommended dosage.

Table3 Folic Acid-related Behaviors among Women of childbearing age (n=4470)

Behaviors	Yes (%)
Folic acid was obtained (free collected or purchased)	3858 (86.3)
Folic acid was taken	3708 (83.0)
Folic acid was taken consistently	3295 (73.7)
Initiation of folic acid supplementation ≥ 3 months before pregnancy	2225 (49.8)
Continuation of folic acid supplementation until 3 months after pregnancy	3276 (73.3)
The recommended dosage was followed	2108 (47.2)
Folic acid supplementation from 3 months before pregnancy to 3 months after pregnancy	2094 (46.8)
Daily folic acid supplementation from 3 months before pregnancy to 3 months after pregnancy	1999 (44.7)
Daily folic acid supplementation at the recommended dosage from 3 months before pregnancy to 3 months after pregnancy	1281 (28.7)

273 **2.1.4 Association of birth defect prevention knowledge with folic acid-related** 274 **behaviors**

275 To assess the relationship between knowledge and folic acid supplementation behaviors, two
276 complementary logistic regression approaches were used.

277 First, a multivariable logistic regression model was fitted with correct daily folic acid

supplementation (defined as taking folic acid daily at the recommended dosage from 3 months before pregnancy to 3 months after pregnancy) as the dependent variable. Knowledge score was entered as the primary independent variable, and age, education level, occupation, residence, parity, and income were included as covariates to adjust for potential confounding (Table 4). After adjustment, knowledge score was significantly and independently associated with correct supplementation (OR = 1.507, 95% CI: 1.43–1.58, $P < 0.001$). Age, occupation, and parity also showed significant associations ($P < 0.05$), whereas education level, residence, and income did not.

Second, binary logistic regression analyses were conducted to estimate the unadjusted effect of knowledge on two sequential behavioral steps: (i) obtaining folic acid (through free collection or purchase) and (ii) taking folic acid daily at the recommended dosage during the full periconceptional period. In these models, knowledge score was the sole independent variable (Table 5). Higher knowledge score was significantly associated with both obtaining folic acid (OR = 1.153, 95% CI: 1.128–1.177, $P < 0.001$) and correct daily supplementation (OR = 1.624, 95% CI: 1.552–1.699, $P < 0.001$). The attenuation of the OR for correct daily supplementation from 1.624 (unadjusted) to 1.507 (adjusted) indicates that part of the crude association is explained by sociodemographic factors; however, the persistence of a strong independent effect in the multivariable model confirms that knowledge remains a robust determinant of optimal adherence.

These findings collectively demonstrate that birth defect prevention knowledge is a consistent predictor of folic acid-related behaviors, with a particularly pronounced influence on the most stringent adherence outcome—daily supplementation at the correct dose throughout the recommended periconceptional window.

Table 4. Multivariable logistic regression analysis of factors associated with folic acid

adherence (n=4470)					
Variable	B	SE	OR	95%CI	P
Knowledge score	0.410	0.025	1.507	1.43-1.58	<0.001
Age(ref=18-25)					<0.001
26-35	-1.627	0.377	0.197	0.09-0.41	<0.001
36-49	-0.260	0.085	0.771	0.65-0.91	0.002
Education(ref= $\leq$ high school)					0.457
Junior college	0.046	0.141	1.047	0.79-1.39	0.746
Bachelor+	0.122	0.098	1.130	0.93-1.37	0.210
Occupation(ref=medical-related)					<0.001
student/unemployed	0.617	0.097	1.854	1.53-2.24	<0.001
non-medical	-0.345	0.222	0.708	0.46-1.09	0.120
Residence (ref=rural)	0.021	0.087	1.022	0.86-1.22	0.807
Parity(ref= $\geq$ 2children)					0.018
1child	-0.418	0.158	0.659	0.48-0.90	0.008
0 child	-0.429	0.153	0.651	0.48-0.88	0.005
Income(ref= $\leq$ 8600)					0.744
8600-47000	-0.034	0.116	0.967	0.77-1.21	0.768
>47000	-0.080	0.116	0.923	0.74-1.16	0.490

300 Note. Knowledge score was entered as a continuous variable (higher scores indicate greater

knowledge). OR = odds ratio; CI = confidence interval; SE = standard error.

Table 5 Association between Birth Defect Prevention Knowledge Scores and Behaviors: a
Binary Logistic Regression Analysis (n=4470)

Behaviors	B	SE	P value	OR	95%CI
Obtained folic acid (free collected or purchased)	0.142	0.011	<0.001	1.153	(1.128,1.177)
whether folic acid was taken daily at the recommended dosage from 3 months before pregnancy to 3 months after pregnancy	0.485	0.023	<0.001	1.624	(1.552,1.699)

Note. Knowledge score was entered as a continuous variable (higher scores indicate greater knowledge). OR = odds ratio; CI = confidence interval; SE = standard error.

2.2 Qualitative study

2.2.1 Sociodemographic characteristics of qualitative interview participants

A total of 18 pregnant women were recruited for in-depth interviews. Participants were aged 28–41 years and had educational level ranging from high school to a master's degree. 100% of participants reported folic acid use; 15 (83.3%) initiated supplementation prior to pregnancy, and 6 (33.3%) adhered to daily intake. Detailed sociodemographic characteristics and folic acid use are shown in Table 6.

2.2.2 Results of qualitative interviews

This study based on the Health Belief Model^[22], systematically analyzed the factors contributing to inadequate folic acid intake among women of childbearing age and reported the findings from five dimensions: insufficient perceived susceptibility to NTDs, insufficient perceived severity of NTDs, insufficient perceived benefits of folic acid supplementation, perceived barriers to folic acid supplementation, and insufficient cues to action.

(1) Insufficient perceived susceptibility to neural tube defects

Based on the “perceived susceptibility” construct of the Health Belief Model, this study found that participants exhibited knowledge gaps in their perception of susceptibility to NTDs. The core issue was a lack of awareness regarding the critical period of neural tube closure. Some participants demonstrated limited or unclear understanding of the timing of neural tube closure, which may lead to inappropriate timing of folic acid supplementation and potentially reduce the effectiveness of preventive behaviors. For example, participant N16 stated, “Does the neural tube close within one month? I didn’t know that—it happens so early,” while N2 reported, “I’m not quite sure when the neural tube closes.”

(2) Insufficient perceived severity of neural tube defects

Based on the “perceived severity” construct of the Health Belief Model, this study found that participants demonstrated insufficient perception of the severity of NTDs. This was mainly reflected in a lack of awareness of the potential harms of NTDs, uncertainty surrounding pregnancy, absence of preconception planning, and forgetfulness.

1) Lack of awareness of the consequences of neural tube defects

Some participants lacked a clear understanding of the specific consequences of NTDs, which

led to a low perceived necessity for folic acid supplementation. Although some participants were aware that folic acid is related to neural tube development, they did not have a clear understanding of the severe outcomes associated with NTDs. Participant N1 indicated that although she knew folic acid is related to neural tube development, she did not understand the developmental process of the neural tube or the consequences of malformations. She stated: “I know folic acid is good for neural tube development, but I don’t really understand how the neural tube develops or what problems can occur if it is malformed. I think health education should clearly explain the consequences of neural tube defects, which might make people take it more seriously.” Another participant, N16, expressed a similar lack of understanding: “My knowledge of folic acid is quite superficial. I don’t have a deep understanding of its specific role. It seems to prevent neural tube defects, but I’m still not very clear about what effects those defects actually have.”

2) Uncertainty surrounding pregnancy

Some participants reported that their timing and attitudes toward folic acid supplementation were commonly influenced by uncertainty surrounding pregnancy. Because the timing of conception is unpredictable, participants often lacked strong motivation to initiate folic acid supplementation during the preconception period. Participant N1 noted: “Before pregnancy, since you don’t know when you will conceive—and nowadays many people say it’s difficult to get pregnant—you may not be particularly motivated to take folic acid. But after becoming pregnant, you would definitely be more conscious about taking it.” Participant N16 stated: “At that time, it was uncertain when pregnancy would happen. If I started taking folic acid during preconception, I might take it for six months without getting pregnant. So although I was aware of it, I didn’t have much motivation. If I would get pregnant after having it within three months, I would definitely

take it. But because the timing is uncertain, I was worried about taking it for too long without conceiving, so I didn't take it regularly." Participant N7 reported: "Pregnancy may not happen immediately, so I didn't take folic acid daily before pregnancy."

3) Lack of preconception planning

Some participants failed to adopt appropriate folic acid supplementation prior to pregnancy, primarily due to insufficient health awareness or lack of preconception planning. These participants reflect gaps in health-related behaviors, resulting in the absence of intentional folic acid use before pregnancy. Participant N13 stated: "No, I didn't plan for pregnancy. I wasn't aware that folic acid should be taken in advance, so I only started taking it after becoming pregnant." Participant N3 reported: "I didn't expect to get pregnant so quickly. I thought it would take two to three months after starting folic acid. At first, I was just preparing for pregnancy and planned to conceive in a two or three months, but I ended up getting pregnant in the first month." Participant N6 noted: "It was an unplanned pregnancy, so I did not take folic acid in advance."

4) Forgetfulness

Some participants' folic acid supplementation behaviors were influenced by daily routines, particularly due to forgetfulness or failure to establish a regular habit, resulting in poor adherence to supplementation. When asked why they did not take folic acid daily, participant N10 stated: "Sometimes I forget, especially when I'm busy—I often don't remember." Participant N4 similarly noted: "I didn't take it every day, mainly because I sometimes forgot. There wasn't any particular reason." Participant N9 reported: "It's definitely hard to take it every day, especially before pregnancy—it's almost impossible to stick to daily use. I do eat vegetables regularly, so I was just concerned about not getting enough. I would take it when I remembered, but not

consistently. For example, if I remembered today, I would take some, or if I saw it, I would take some.”

(3) Insufficient perceived benefits of folic acid supplementation

Based on the “perceived benefits” construct of the Health Belief Model, this study found that participants had knowledge gaps regarding the benefits of folic acid supplementation. This was mainly reflected in a lack of understanding of the specific benefits of folic acid and the necessity of supplementation in addition to dietary intake.

1) Lack of understanding of the specific benefits of folic acid

Many participants demonstrated limited understanding of the specific benefits of folic acid. Although most were aware that folic acid is beneficial, they had insufficient knowledge regarding its specific roles in maternal and fetal health, how it functions, and the mechanisms underlying its preventive effects. Participant N11 stated: “I’m not very clear about the specific effects of folic acid—how beneficial it is for the mother or the baby. The concept is still quite vague. It should be explained in a more straightforward way so that everyone can understand its benefits. I’ve also seen online discussions where people consider it a kind of medicine and say things like ‘all medicines have some toxicity,’ and some even say that babies can still develop well without taking folic acid. I think this may be due to inadequate health education.” Participant N13 noted: “I would like to know the specific functions of folic acid, its benefits, and what problems it can prevent.” Participant N16 reported: “I haven’t looked into folic acid in depth. Although I know it is used to prevent certain problems, I’m still not very clear about what exactly it prevents.”

2) Lack of awareness of the necessity of supplementation beyond dietary intake

Some participants lacked sufficient understanding of the necessity and importance of folic acid

supplementation. This was reflected in the belief that folic acid does not need to be obtained through supplements and a limited awareness of its functions and potential health benefits. Folic acid supplementation was often viewed as optional, with a preference for obtaining folate from dietary sources rather than from supplements. Participant N14 stated: “I don’t think it’s necessary to take folic acid every day—not because it’s difficult, but because I feel it’s unnecessary. I don’t usually buy supplements, including iron supplements in late pregnancy. I’m not particularly concerned about these because I don’t feel deficient. I believe it’s more important to obtain nutrients from food, and I tend to think that getting them from diet is better.” Participant N3 reported: “Folic acid tablets are not absolutely necessary. Not taking them does not seem to lead to immediate consequences. I think eating some fruits can also help supplement it. When I had severe morning sickness, I stopped taking them, and so far I haven’t noticed any negative effects.” Participant N7 noted: “I think folic acid doesn’t have to be supplemented only through medication—vegetables also contain folate. So I don’t think it’s necessary to take it every day. Excessive intake might increase metabolic burden, so I prefer not to take folic acid tablets daily.”

(4) Perceived barriers to folic acid supplementation

Based on the “perceived barriers” construct of the Health Belief Model, this study found that participants faced multidimensional knowledge-related barriers in practicing folic acid supplementation. These were mainly reflected in a lack of knowledge regarding dietary sources of folate, the appropriate duration of supplementation, and the recommended dosage. In addition, some participants perceived potential side effects and were unclear about the significance of folate metabolism testing.

1) Lack of knowledge of dietary sources of folate

Some participants demonstrated limited knowledge of dietary sources of folate and lacked a clear understanding of which foods are rich in folate in their daily diet. This knowledge gap may affect their ability to obtain adequate folate through dietary intake, particularly when folic acid supplementation is not taken timely or regularly. When asked about remaining questions regarding folic acid, participant N13 stated: “What foods should I pay attention to in order to help increase folate intake?”

2) Uncertainty about the duration of folic acid supplementation

Some participants expressed uncertainty regarding the appropriate duration of folic acid supplementation, particularly whether supplementation should be continued after getting pregnant. Participant N16 stated: “I’ve always had a question— folic acid for three months before pregnancy is recommended, but I’m not sure whether it should be continued after becoming pregnant, or whether it can be taken beyond the first three months of pregnancy.”

3) Uncertainty about the appropriate dosage of folic acid

Some participants were uncertain about the appropriate dosage of folic acid, particularly in the absence of individualized guidance. Participant N6 stated: “I do have this concern—I’m not sure whether I actually have a folate deficiency, and I don’t know how much I should take. For example, the medication I bought says to take one tablet per day, but I’m not sure whether that is really suitable for me or tailored to my individual situation.”

4) Concerns about potential side effects

Some participants expressed concerns about the potential side effects of folic acid supplementation. These concerns were largely rooted in general perceptions of medications or supplements, particularly worries about possible negative effects associated with long-term use.

Participant N11 stated: “I’ve seen online discussions where people consider it a kind of medicine and say things like ‘all medicines have some toxicity.’” Participant N16 noted: “I feel that taking folic acid every day isn’t very good—it feels like taking medicine, and I always think that ‘all medicines have some toxicity.’” Participant N7 reported: “I don’t think it’s necessary to take folic acid every day. Excessive intake might increase metabolic burden.”

5) Uncertainty about the significance of folate metabolism testing

Some participants expressed confusion regarding the significance of folate metabolism testing. They were unable to clearly understand how the test results informed actual folic acid supplementation practices. Participant N2 stated: “Before I got pregnant, the doctor prescribed standard folic acid. After pregnancy, they conducted a folate metabolism test. When I looked into it myself, I found that some people suggested taking activated forms, which seem to be different. However, after reviewing the test results, the doctor still recommended standard folic acid. So I feel that the test may not be very necessary, because regardless of whether you take it or not, you still end up taking the same folic acid, and its significance does not seem very substantial.”

(5) Insufficient cues to action

Based on the “cues to action” construct of the Health Belief Model, this study found that barriers existed in the promoting mechanisms of folic acid supplementation behaviors. These were mainly reflected in insufficient personalized recommendations from the internet, the need to critically filter online information, and inadequate health education from healthcare providers.

1) Insufficient personalized recommendations from online sources

Online platforms and internet-based resources were perceived to provide insufficient personalized recommendations regarding folic acid supplementation. As a result, participants were

466 unable to obtain tailored guidance based on their individual circumstances, which in turn affected
467 their supplementation behaviors. Participant N3 stated: “The information they provide is quite
468 comprehensive, but it is very general. When applied to an individual, it still requires personal
469 adjustment.” Participant N6 noted: “The quality is sometimes poor because the information is
470 quite broad and not tailored to my personal situation. For example, I don’t know whether I am
471 deficient in folate or how much I should take.” Participant N8 reported: “I think everyone’s
472 situation is different, so the information provided may not be suitable for me. I believe this kind of
473 health education is better delivered one-on-one—consulting a doctor based on individual
474 circumstances may be more effective.” Participant N9 stated: “It is indeed convenient to obtain
475 information online, but the content pushed by public accounts is based on their own perspective
476 and may not meet my actual needs. In contrast, offline consultations are usually driven by specific
477 questions, allowing for more targeted communication with doctors and yielding different
478 outcomes.”

479 2) The need to filter and evaluate online information

480 Some participants reported that the quality of information available on the internet varies
481 considerably, and that information overload or misleading content often requires them to actively
482 filter and verify what they encounter. This situation affected their understanding and practice of
483 folic acid supplementation. Participant N10 stated: “I need to review multiple sources and cross-
484 check information to ensure its accuracy, and to filter out content that may be overly extreme.”
485 Participant N1 noted: “I feel that even very small risks are unlikely to happen to me, but platforms
486 like TikTok often push this kind of content, which can increase anxiety among pregnant women. I
487 think it’s important to learn how to filter information, because not everything online is reliable.”

488 Participant N18 reported: “Online information is quite comprehensive, but sometimes excessive.
489 Some sources recommend taking active forms of folate, suggesting possible metabolic issues, and
490 these are quite expensive. However, other health education materials indicate that standard folic
491 acid is enough.” Participant N2 stated: “When you don’t understand something, you can refer to
492 online information, but only as a reference—you shouldn’t rely on it completely.” Participant N5
493 noted: “You need to evaluate information yourself and consult different professionals. Some
494 information may be false, so you may have to go through some trial and error before making your
495 own judgment.” Participant N6 reported: “Yes, it can be useful, but the key is to remove
496 unnecessary information, filter out what is not useful, and retain what is relevant.” Participant N8
497 stated: “I think the quality of information on the internet is quite inconsistent, so I don’t rely on it
498 much.”

499 3) Inadequate health education

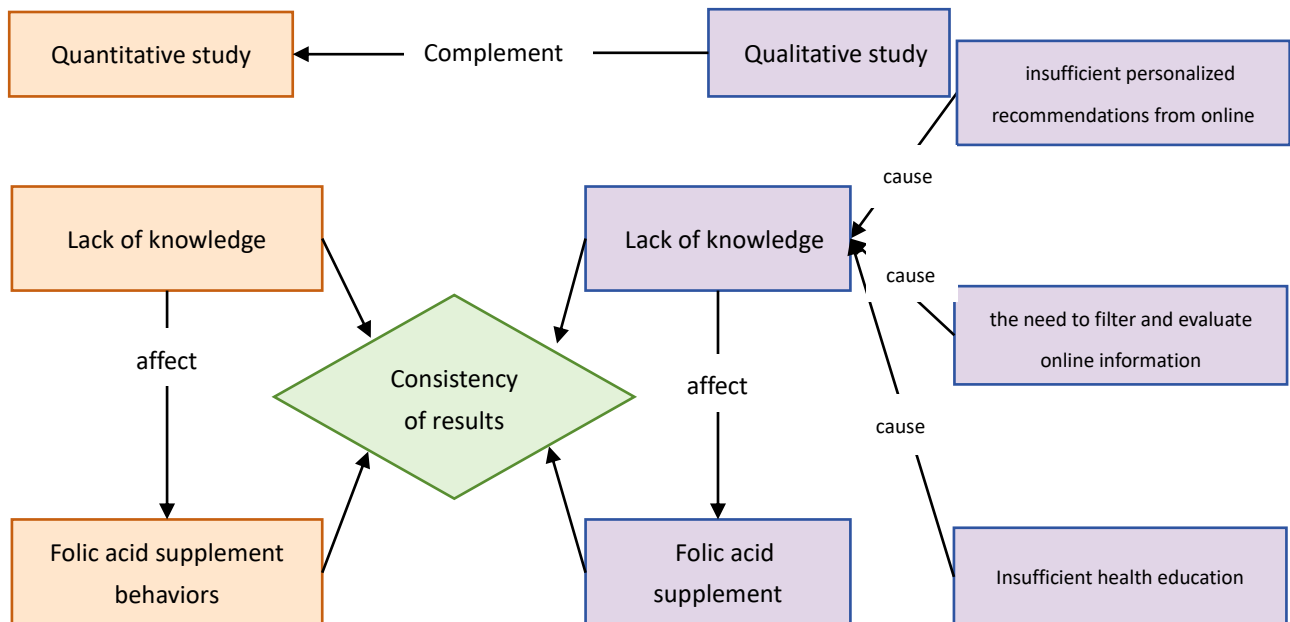
500 Some participants reported insufficient health education from healthcare providers regarding
501 folic acid supplementation, particularly in explaining its specific benefits and its role in preventing
502 NTDs. Although doctors and nurses clearly advised them to take folic acid, detailed explanations
503 about its functions and preventive effects were often lacking, resulting in a limited understanding
504 of its necessity and effectiveness. Participant N11 stated: “Doctors and nurses only told me that I
505 needed to take folic acid, but they didn’t explain its specific benefits or why I should take it. They
506 just briefly advised me to take it.” Participant N13 noted: “The doctor told me to take folic acid,
507 and after some time said I could stop. There was no further explanation. They didn’t clearly
508 explain how folic acid helps prevent malformations. That’s all I know—I don’t really understand
509 much beyond that.” Participant N2 reported: “They just said I should take it, without much

additional explanation—it was mentioned very briefly.” Participant N7 stated: “They only said that I need to take it, but didn’t explain much about why it is necessary.”

2.3 Joint display of mixed methods results

The joint display of mixed methods results is presented in Figure 1. The quantitative results showed a significant negative correlation between lack of knowledge and adherence to folic acid supplementation. Further thematic analysis of the qualitative study revealed that the causes of insufficient knowledge were associated with the following three aspects: (1) insufficient personalized recommendations from online sources; (2) the need to filter and evaluate online information; and (3) insufficient healthcare education. These three factors contributed to inadequate knowledge of folic acid among women of childbearing age, thereby indirectly affecting their folic acid supplementation behaviors.

Figure 1 Joint display of mixed methods results



In addition, the interviews revealed several key questions that participants repeatedly raised regarding knowledge of folic acid intake. Rooted in participants' verbatim responses, these

questions concretize the specific cognitive gaps underlying the observed discrepancy between high awareness and low adherence. This study summarized six core questions, as shown in Table 7. These findings provide an intuitive illustration of the specific manifestations of knowledge deficits—particularly concerning the timing of neural tube closure, the necessity of preconception initiation, and dietary versus supplemental sources—and help explain why only 28.7% of women achieved adequate folic acid supplementation.

Table7 Core questions

questions	resources
(1) What is neural tube defects?	N1\N2\N16
(2) What role does folic acid play in the prevention of neural tube defects	N11\N13\N16
(3) Why is it necessary to take folic acid before pregnancy?	N1\N3\N6\N7\N13\N16
(4) What are the differences in the timing and dosage of folic acid intake among populations with different risk levels?	N2\N6\N16, qualitative study
(5) Is additional folic acid testing required?	N2
(6) Is it sufficient to obtain folic acid solely from dietary sources?	N3\N7\N14

3 Discussion

This study focuses on folic acid supplementation behavior among women of reproductive age. Currently, there is a notable disconnect between folic acid supplementation practices and

related knowledge awareness in this population. Although most participants demonstrated a high level of awareness regarding the important role of folic acid in preventing NTDs, significant deficiencies remain in key aspects of actual supplementation behavior, such as timing of initiation, adherence to continuous use, and standard dosage. The following section provides a detailed discussion of the issues reflected in the data and the underlying mechanisms.

In folic acid supplementation behavior, the rates of folic acid acquisition (86.3%) and intake (83.0%) were relatively high; however, the proportion of individuals strictly adhering to the correct timing and dosage was only 28.7%. These data indicate that while most women of childbearing age have a certain level of awareness concerning the importance of birth defect prevention, there remains room for improvement in the timing of early folic acid initiation, daily adherence, and dosage compliance. This finding is similar to a study conducted in Yunnan Province, where the folic acid intake rate was as high as 93.81%, but the rate of compliant intake was only 47.16%^[24]. This suggests that even when women take folic acid, barriers still exist that prevent correct supplementation behavior. A similar situation has also been observed in rural areas of Gansu Province, where, despite an increasing intake rate over the years, compliance and sustainability still require improvement^[25, 26].

In terms of knowledge about folic acid, this study found that although 95.6% of respondents were aware that folic acid prevents neural tube defects, and demonstrated a high level of awareness regarding access pathways through health policies (89.0%) and dietary sources (94.4%), awareness rates for key operational indicators—namely the supplementation time window (62.6%) and the recommended dosage (51.4%)—were notably low. This is similar to findings from a study in Switzerland, which reported that although 88% of participants were aware

of the preventive effect of folic acid against neural tube defects, their understanding of specific supplementation recommendations was limited^[27].

This reflects a pattern of “high intake–low compliance” in folic acid supplementation behavior among women of childbearing age. Further interviews revealed the presence of multiple barriers in the knowledge–behavior translation mechanism, with the pathways of influence primarily manifested in the following dimensions:

First, cognitive biases regarding key knowledge elements directly affect supplementation adherence. For example, some participants held serious misconceptions about the timing of neural tube closure (e.g., N16 mistakenly believed that “closure occurs one month later”), leading them to overlook the urgency of preconception supplementation. Although other participants were aware that folic acid prevents neural tube defects, they lacked an understanding of its specific mechanisms of action (such as DNA synthesis and methylation regulation) (N13: “I want to know the specific purpose and preventive mechanism”), resulting in behavioral motivation that remained at the level of passive compliance rather than active internalization. More notably, insufficient knowledge gave rise to the misperception that “dietary sources can replace supplementation” (N14: “It’s better to get it from food”; N7: “Vegetables contain folic acid, so there is no need to take it every day”). Participants overestimated the bioavailability of dietary folate while failing to recognize the loss rate of natural folate during cooking (approximately 50–90%) and the high stability of synthetic folic acid^[16]. This cognitive bias directly contributed to inadequate folic acid levels during the critical window of the first trimester. Furthermore, generalized statements from online information such as “all medications have side effects” (N11, N16), combined with excessive concerns about folic acid overdosing (N7: “increases metabolic burden”), created a

cognitive imbalance that further weakened supplementation adherence.

Second, there is a structural contradiction between the mode of health information dissemination and individual cognitive needs. Interviews revealed that healthcare education often remains at the level of instructing patients to “take it” (N11: “The doctor just said I need to take it, without explaining why”), lacking explanations regarding the rationale for dosage adjustments (e.g., differences in metabolic genotypes) or the scientific basis for the supplementation time window (neural tube closure occurs before 6 weeks of gestation). This prevents knowledge from being translated into actionable strategies. Meanwhile, the generality (N3: “The information is general and requires self-adjustment”) and contradictory nature of online information (N18: “There is controversy over active folic acid”) compel participants to invest considerable effort in verifying information (N10: “I need to cross-reference and filter”), resulting in a cycle of information overload and decision paralysis.

Furthermore, behavioral adherence is dynamically influenced by multiple factors. Pregnancy uncertainty (N16) and occasional forgetfulness constitute practical barriers; however, these factors amplify risks through interaction with knowledge gaps. Individuals with a systematic understanding can mitigate the risk of adverse outcomes through remedial supplementation (initiating immediately after conception), whereas those lacking adequate knowledge may completely miss the intervention window.

Using a mixed-methods design, this study conducted a large-scale investigation of the knowledge, behaviors, and in-depth barriers related to folic acid supplementation among women of childbearing age across mainland China. The broad geographic coverage of the questionnaire survey enhanced the representativeness of the findings. Meanwhile, the qualitative interviews,

based on the Health Belief Model, provided an in-depth exploration of the barriers to folic acid supplementation. The quantitative and qualitative findings were consistent. This study provides a scientific basis for developing targeted health education strategies and comprehensive behavioral models, thereby more effectively improving folic acid supplementation adherence among women of childbearing age and reducing the risk of neural tube defects. The data sources primarily rely on questionnaire surveys and interviews. Although the questionnaire covers a relatively broad population of women of childbearing age, the interviews were limited to women attending the obstetrics department of a specific hospital. This sample has certain limitations in terms of geographic, cultural, and health backgrounds, which may lead to the omission of some folic acid-related concerns among women of childbearing age. Future research should expand sample diversity, particularly by conducting larger-scale surveys across different regions, cultural backgrounds, and healthcare resource settings, to ensure a more comprehensive inclusion of real-world folic acid concerns among women of childbearing age.

4 Strengths and limitations

This study has several notable strengths. First, the mixed-methods design enabled a comprehensive investigation that moves beyond prevalence estimation to elucidate the cognitive and informational mechanisms underlying the observed knowledge–behavior discrepancy. The integration of a large-scale quantitative survey (n=5,741 across diverse regions of China) with in-depth qualitative interviews, systematically guided by the Health Belief Model, provides both breadth and explanatory depth, thereby enhancing the credibility and practical relevance of the findings. Second, the joint display of mixed-methods results offers a transparent synthesis of how knowledge deficits interact with generic health messaging and brief provider counseling to

produce suboptimal adherence. Third, the theoretical grounding facilitates identification of modifiable barriers—perceived susceptibility, severity, benefits, and cues to action—that can directly inform targeted intervention design.

Several limitations should also be acknowledged. First, convenience sampling and the overrepresentation of healthcare workers and highly educated participants may limit generalizability and potentially overestimate population awareness and adherence. Second, the qualitative sample was recruited from a single urban tertiary hospital, which may underrepresent perspectives from rural populations or women not yet engaged in pregnancy planning. Third, all behavioral data were self-reported and thus subject to recall bias; objective biomarkers of folate status were not available to validate adherence. Fourth, the cross-sectional design precludes causal inference regarding the temporal relationship between knowledge acquisition and behavioral change. Future research should employ probability-based sampling, longitudinal designs, and biomarker validation to address these limitations.

5 Conclusions

This study comprehensively explored the barriers to folic acid supplementation among women of childbearing age and directions for improvement through a questionnaire survey and semi-structured interviews. The findings indicate that although most women are aware of the basic role of folic acid, significant knowledge gaps remain regarding the correct timing, dosage, and individualized needs for supplementation. The current modes of health education dissemination are homogeneous and lack specificity, further limiting the effectiveness of folic acid knowledge promotion.

643 **List of abbreviations**

644 Neural tube defects (NTDs)

645

Table 1 Distribution of Demographic Variables (n=5741)

Variables	Characteristic	n	%
Regions	Eastern	871	15.2
	Northeastern	322	5.6
	Central	2820	49.1
	Western	1728	30.1
Age	18-25	906	15.8
	26-35	2427	42.3
	36-49	2408	41.9
Occupation	Students	410	7.1
	Government employees / State-owned enterprise employees / Public institution staff	849	14.8
	Agricultural, forestry, animal husbandry, and fishery workers	78	1.4
	Private sector employees	700	12.2
	Healthcare workers (including both public and private sectors)	2713	47.3
	Self-employed individuals	532	9.3

	Others	459	7.9
Education level	High school or below (including technical school)	1073	18.7
	College or undergraduate degree	4304	75.0
	Master's degree or above	364	6.3
Medical background	Yes	3583	62.4
	No	2158	37.6
Income	<8600	2435	42.4
	8600-19300	1207	21.0
	19301-30000	654	11.4
	30001-47000	638	11.1
	47001-90000	455	8.0
	≥ 90001	352	6.1
Household registration	Urban	2858	49.8
	Rural	2883	50.2
Place of residence	Urban	4312	75.1
	Rural	1429	24.9
Migrant status	Yes	725	12.6
	No	5016	87.4

Marital status	Yes		4441	77.4
	No		1300	22.6
Number of children	No children		1624	28.3
	One child		2018	35.2
	Two or more children		2099	36.5

646

Table6 Sociodemographic Characteristics of Participants and Folic Acid

Supplementation					
ID	Age (year)	Education level	Folic acid use (Yes/No)	Preconception folic acid use (Yes/No)	Frequency of intake
N1	36	Bachelor's degree	Yes	Yes	2-3 times per week
N2	32	High school	Yes	Yes	2-3 times per week
N3	33	Master's degree	Yes	Yes	daily
N4	29	Master's degree	Yes	Yes	2-3 times per week
N5	41	Bachelor's degree	Yes	Yes	1-2 times per week
N6	39	High school	Yes	No	2-3 times per week
N7	35	Associate degree	Yes	Yes	3-4 times per week

N8	34	Bachelor's degree	Yes	Yes	daily
N9	34	Associate degree	Yes	Yes	3-4 times per week
N10	35	Associate degree	Yes	Yes	daily
N11	35	Master's degree	Yes	Yes	daily
N12	32	Bachelor's degree	Yes	Yes	3-4 times per week
N13	29	Bachelor's degree	Yes	No	3-4 times per week
N14	31	Associate degree	Yes	Yes	1-2 times per week
N15	29	Bachelor's degree	Yes	Yes	daily
N16	30	Associate degree	Yes	Yes	5-6 times per week
N17	28	Bachelor's degree	Yes	No	daily

N18	33	High school	Yes	Yes	2-3 times per week
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Declare

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Peking University Biomedical Ethics committee (Approval No: IRB00001052-24088). Oral informed consent was obtained from all participants prior to data collection.

Clinical trial number

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

Li JH (Jiahe Li) contributed to conceptualization, methodology, investigation, data analysis, and writing the original draft. Peng X (Xiang Peng) contributed to data analysis and writing the original draft. He H (Hongxiao He) contributed to methodology. Liu N (Ning Liu) contributed to investigation and data analysis. Dong W (Wenjia Dong) contributed to investigation. Lv D (Dandan Lv) contributed to investigation. Li SJ (Shuangjin Li) contributed to investigation. Zhu X (Xiu Zhu) contributed to conceptualization, methodology, supervision, and project administration. All authors read and approved the final manuscript.

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