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Epidemiological features of pediatric nonalcoholic fatty liver disease in China

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Abstract

Objective Non-alcoholic fatty-liver disease (NAFLD) among children and adolescents in China has emerged as a significant public-health concern, that requires greater attention. This study aims to estimate the prevalence of pediatric NAFLD and its epidemiological characteristics.

Methods Four English-language and two Chinese-language databases were systematically searched for relevant articles published before January 1st, 2025. Rigorous inclusion and exclusion criteria were applied to screen articles and extract NAFLD prevalence data. The pooled overall prevalence of NAFLD with 95% confidence intervals (CIs) was calculated using the Freeman-Tukey Double Arcsine Transformation Method. Moreover, subgroup analysis was conducted to compare NAFLD prevalence across different categories, including region, income, age, and gender.

Results The study encompassed 126,682 participants from 219 studies. The nationwide prevalence of pediatric NAFLD in China was 22.82%. Higher prevalence rates were observed among boy, older age groups, individuals in southern and northeastern regions, and those classified as obese or overweight. Furthermore, epidemiological pattern analysis of children with NAFLD identified metabolic, endocrine, and lifestyle factors as crucial determinants in pediatric NAFLD progression.

Conclusions Considering the substantial burden of pediatric NAFLD in China, researchers must conduct effective intervention studies to address its epidemiological status. Additionally, governmental action is required to enhance public awareness and establish health policies aimed at controlling the NAFLD epidemic among Chinese children.

Trial registration The registration number was CRD42020206731.

Keywords Nonalcoholic fatty liver disease, Prevalence, Epidemiological, Pediatric, China

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Introduction

Nonalcoholic fatty liver disease (NAFLD) is a major global chronic liver disease epidemic affecting 25% of the population [1]. China has experienced a rapid increase in NAFLD prevalence due to improved living standards. Previous research projects that NAFLD cases in China will reach 314.58 million by 2030 [2]. Notably, recent studies indicate that China will experience the highest annual NAFLD-related mortality worldwide [3].

The increasing trend of obesity among younger populations appears to contribute significantly to China's high adult NAFLD incidence rate. Research indicates a dramatic rise in childhood and adolescent obesity worldwide, particularly in China [4, 5]. These findings suggest that pediatric NAFLD may be a precursor to the adult liver disease burden in China. Addressing NAFLD in children could potentially resolve this public health challenge at its source. Thus, understanding the epidemiological characteristics of pediatric NAFLD in China has become crucial [6].

While previous studies have analyzed adult NAFLD epidemiological characteristics in China, they have not adequately addressed children and adolescents [3, 7]. A global meta-analysis from 2015 revealed that the prevalence of pediatric NAFLD stood at 34.2%. However, this analysis included only five studies from China [8]. The present research aim to employs a comprehensive yet rigorous search strategy to determine pediatric NAFLD prevalence in China, conducting detailed subgroup analyses based on epidemiological characteristics including region, income, age, and gender.

This study's findings hold significant implications for addressing pediatric NAFLD in China. The data will provide researchers and government officials with a deeper understanding of the challenges and characteristics related to pediatric NAFLD in China. Future public health interventions incorporating Chinese characteristics are essential to address nationwide childhood NAFLD.

Methods

Search strategy and selection criteria

This study has registered a comprehensive protocol in the International Prospective Register of Systematic Reviews (PROSPERO) database and strictly followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines [9]. The registration number was CRD42020206731. Two authors (XP and AK) independently searched four English-language database (Web of Science, PubMed, Embase, and Cochrane Library) and two Chinese-language databases (China National Knowledge Infrastructure and Wanfang) from database inception to January 1 st, 2025. The search strategy, along with the comprehensive search terms, was formulated by seasoned medical librarians. There are no language restrictions for inclusion in the study, with all languages having been translated into English. Boolean operators, wildcard characters, and truncation extensively utilized within the search strategy to ensure the most thorough and rigorous search approach feasible. The search strategy is given in the Appendix 1 and 2.

The inclusion criteria were as follows: (1) Studies of a cross-sectional or longitudinal observational; (2) Chinese children and adolescents ranging in age from 1 to 19 years old; (3) reported the number of patients with NAFLD and the total population. The excluded criteria were as follows: (1) animal study or in vitro experiments study; (2) paper type is not original research, such as review article, conference paper, case report, letter, or abstract only; (3) a study reported on patients with NAFLD and comorbid liver conditions, including HBV, HCV, and auto-immune hepatitis; (4) a detailed comparison was conducted between studies implemented within the same region. After reaching out to the corresponding authors, studies with overlapping populations were excluded, and only the one with the larger sample size was retained.

Data analysis

After applying the inclusion and exclusion criteria to the article, two independent investigators (AL and AK) extracted the relevant data. Meta analysis was employed to estimate the prevalence of pediatric NAFLD, with 95% confidence intervals (CIs) provided. Variance stabilization was achieved through the application of the Freeman-Tukey double arcsine transformation method. Given the substantial heterogeneity of different studies, the random-effects model was adopted in this research. Moreover, Cochran's Q statistic and I^2statistic were used to quantify the heterogeneity among studies. Considering that the lack of a clear definition or consensus about what constitutes a positive result in a meta-analysis of proportions, this study assess publication bias qualitatively [10]. To quantify the research included in the study and ensure quality control, the risk of bias of was assessed using Newcastle-Ottawa Scale (NOS) tool according to different types of study. Additionally, to evaluate the impact of various factors on the prevalence of NAFLD, subgroup analyses and meta-regression were done with the following covariates: gender, region, study setting, age, populations, diagnostic method, GDP per capita, sample size, and year of publication. We also did word cloud analysis of detailed epidemiological determinants of pediatric NAFLD. All analyses were two-sided, analyzed using R statistical software (version 4.0.3), and $p < 0.05$ was considered statistically significant.

Results

Literature search

The literature search yielded 4,535 studies. After removing duplicates and reviewing abstracts, 2,944 studies were excluded. Following a full-text screening of 1,591 studies, 219 studies met the inclusion criteria for this meta-analysis (Appendix 3 and Fig. 1).

Characteristics of eligible studies

This meta-analysis encompassed 126,682 children and adolescents. The characteristics of included studies are detailed in Appendix 4, 5, and 6. The regional distribution comprised 20 studies from the central region, 103 from the east region, 37 from the north region, 18 from the northeast, 13 from the northwest, 4 from the southwest, and 24 from the south region of China. Regarding GDP per capita levels, 3 studies were from low-income regions, 20 from high-income regions, 83 from lower-middle-income regions, and 113 from middle-income regions. The sample sources included 131 hospital-based and 88 population-based studies. Quality assessment revealed 169 studies with low risk of bias and 50 with moderate risk of bias. Age group distribution showed 76 young adolescents, 35 children, and 108 adolescents.

The number of NAFLD, NAFL, and NASH cases are presented in Appendix 7. The characteristics of included studies investigating clinical complications and risk factors of pediatric NAFLD are detailed in Appendix 8. Common complications of pediatric NAFLD included T2DM, IR, altered glucose, lipid and uric metabolism, hypertension and metabolic syndrome. Common risk factors comprised age, BMI, waist-hip ratio, hypertension, ALT, AST, uric acid, GGT, LDL-C, HDL-C, and Triglyceride.

Prevalence of pediatric NAFLD in China

The prevalence of pediatric NAFLD was stratified by age, gender, region, surveillance model, severity, income, population type, year of publication, and sample size, as shown in Table 1. The provincial distribution of NAFLD prevalence is illustrated in Fig. 2A, with Heilongjiang province showing the highest prevalence. Figure 2B displays the NAFLD prevalence across different provinces. Regarding temporal distribution, the highest prevalence was recorded in 1997. The prevalence patterns varied by year and geographical region (Fig. 2C and D).

Among age groups, the 15–18 age group demonstrated the highest prevalence of pediatric NAFLD (25.02%; 95% CI, 22–28). The northeast region showed the highest regional prevalence (41.18%; 95% CI, 34–51), while the low-income group exhibited the highest prevalence among income categories (29.54%; 95% CI, 17–51). The HRMS group showed the highest prevalence among diagnostic techniques (61.54%; 95% CI, 55–69). The 2016–2020 period showed the highest prevalence for publication year (31.34%; 95% CI, 26–38). Among population types, the obese group demonstrated the highest prevalence (43.20%; 95% CI, 41–46). The nationwide prevalence of pediatric NAFLD was determined to be 22.82% (95% CI, 0.21–25.21), as illustrated in Fig. 3.

Pediatric NAFLD prevalence stratified by different subgroups

The stratified prevalence analysis by different subgroups is presented in Table 2. Boys (24.75%; 95% CI, 23–27) showed higher prevalence than girls than girl (20.12%; 95% CI, 17–24). The hospital-based (37.31%; 95% CI, 35–40) studies reported higher prevalence than population-based studies (14.03%; 95% CI, 12–16). Regional analysis revealed higher prevalence in the south (24.98%; 95% CI, 22–28) compared to the north (20.05%; 95% CI, 17–23), lower prevalence in the Northwest (13.40%; 95% CI, 9–20) compared to both Northeast (41.18%; 95% CI, 34–51). The 2016–2020 (31.34%; 95% CI, 26–38) period showed higher prevalence than 2011–2015 (19.09%; 95% CI, 16–23). Among population types, obese individuals (43.20%; 95% CI, 41–46) demonstrated higher prevalence than both overweight (17.33%; 95% CI, 14–21) and non-obese groups (5.02%; 95% CI, 04–06).

Meta-regression analysis results are presented in Fig. 4. While year, GDP, and age showed no significant associations, gender emerged as a significant factor ($t = 3.850$, $p < 0.001$) in explaining heterogeneity. Given the large number of studies in this epidemiological meta-analysis, leave-one-out analysis provided limited insight. Publication bias assessment considered multiple factors: comprehensive searches across six databases and inclusion of grey literature, although letters and editorial comments were excluded. The likelihood of publication bias in this study is minimal.

Figure 5 presents a word cloud analysis of epidemiological determinants of pediatric NAFLD. Among metabolic risk factors, abdominal obesity, hyperlipidemia, hypertension, metabolic syndrome, increased BMI, SBP, DBP, WC, weight, HOMA-IR, IR, WHR, and WHtR have been identified as risk factors for pediatric NAFLD. Endocrine risk factors, including elevated ALT, AST, FINS, GGT, UA, LDL-C, TC, and TG were associated with progressive NAFLD, while increased adiponectin and HDL-C demonstrated protective effects. Regarding lifestyle and demographic factors, male gender, family history, consumption of fried food, advanced age, insufficient physical exercise, and snacking contribute to NAFLD development. Concerning hereditary factors, PNPLA3 rs738409, MTTP rs2306986, MTTP rs3792683, GCKR rs780094, and TM6SF2 rs58542926 have been established as risk factors for pediatric NAFLD.

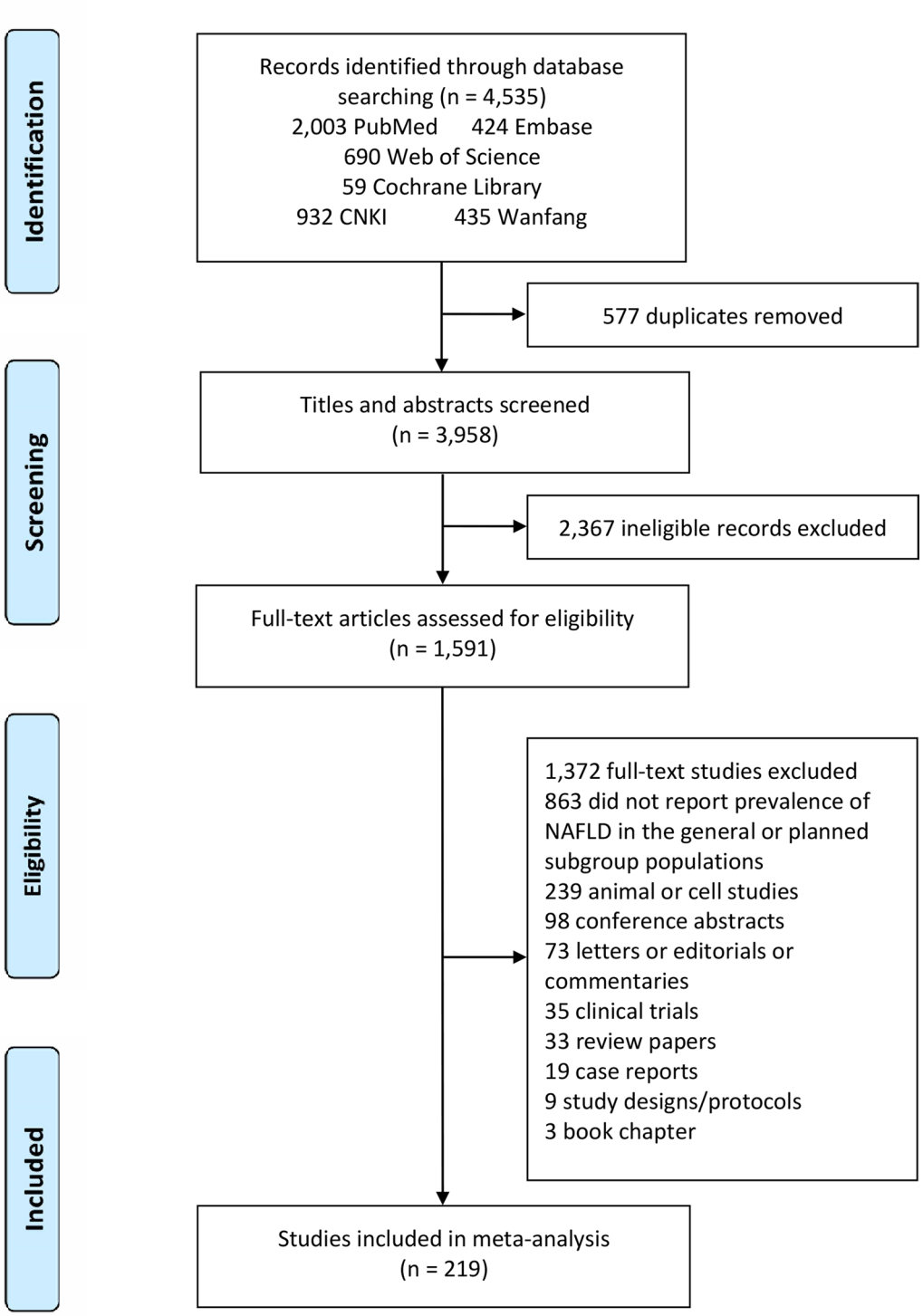


Fig. 1 Flow chart of the study selection. A flow chart demonstrating the selection process of articles included in the analysis as well as in the qualitative summary. NAFLD, non-alcoholic fatty liver disease

Discussion

The epidemiological state on pediatric NAFLD

This meta-analysis represents the largest study examining the prevalence of pediatric NAFLD in China, providing a comprehensive assessment across temporal and spatial dimensions. The nationwide prevalence of NAFLD in the general pediatric population maintains normal levels, while obese children exhibit significantly higher rates. Specifically, the prevalence in non-obese populations stands at 5.02%, below the global average of 7.6%.

Table 1 NAFLD prevalence stratified by different subgroups

Subgroup	Total sample	Prevalence (%)	95% CI		Heterogeneity			*p*
	Size				Q statistic (DF; *p*-value)	τ^2	I^2 (%)	
Age								
15–18	61,882	25.02	0.22	0.28	17198.43 (160; < 0.0001)	0.53	99.1	
10–14	36,975	20.76	0.18	0.24	7674.61 (113; < 0.0001)	0.7	98.5	*0.120*
< 10	27,825	21.08	0.17	0.26	5314.26 (61; < 0.0001)	0.62	98.9	
Region								
Northwest	14,052	13.4	0.09	0.2	2518.80 (25; < 0.0001)	0.9	99	
South China	6,727	25.59	0.21	0.32	896.08 (29; < 0.0001)	0.31	96.8	
Northeast	2,081	41.18	0.34	0.51	948.94 (21; < 0.0001)	0.2	97.8	
Southwest	1,235	9.17	0.04	0.2	164.37 (8; < 0.0001)	1.27	95.1	***< 0.001***
East China	68,019	26.26	0.23	0.3	14872.30 (150; < 0.0001)	0.56	99	
North China	24,665	18.91	0.16	0.23	3729.57 (62; < 0.0001)	0.58	98.3	
Central China	9,903	20.88	0.15	0.28	2577.46 (35; < 0.0001)	0.8	98.6	
Surveillance model								
Hospital-based	33,235	37.31	0.35	0.4	7718.59 (171; < 0.0001)	0.21	97.8	***< 0.001***
Population-based	93,447	14.03	0.12	0.16	14130.61 (164; < 0.0001)	0.84	98.8	
Severity								
NAFL	126,056	21.72	0.2	0.24	30519.11 (332; < 0.0001)	0.64	98.9	
								0.026
NASH	4,077	25.3	0.2	0.32	390.07 (23; < 0.0001)	0.28	94.1	
Geographic								
North	50,133	20.05	0.17	0.23	15068.65 (137; < 0.0001)	0.69	99.1	***0.016***
South	76,549	24.98	0.22	0.28	15776.31 (198; < 0.0001)	0.53	98.7	
Income								
Lower middle income	27,045	23.5	0.2	0.27	5916.60 (105; < 0.0001)	0.49	98.2	
Middle income	88,157	21.97	0.2	0.25	23305.27 (199; < 0.0001)	0.65	99.1	*0.373*
Low income	243	29.54	0.17	0.51	14.61 (2; 0.0007)	0.19	86.3	
High income	11,237	26.95	0.21	0.34	1609.18 (27; < 0.0001)	0.4	98.3	
Diagnostic technique								
USS	105,856	23.38	0.22	0.25	26240.47 (327; < 0.0001)	0.51	98.8	
ALT	20,515	7.83	0.04	0.15	451.35 (5; < 0.0001)	0.69	98.9	***< 0.001***
HRMS	182	61.54	0.55	0.69	--	--	--	
MRS	129	51.61	0.41	0.64	--	--	--	
Gender								
Boy	68,395	24.75	0.23	0.27	14879.57 (219; < 0.0001)	0.46	98.5	***0.042***
Girl	58,287	20.12	0.17	0.24	16700.70 (116; < 0.0001)	0.9	99.3	
Year of publication								
2001–2005	9,780	28.84	0.25	0.34	1830.17 (56; < 0.0001)	0.32	96.9	
2006–2010	38,950	23.17	0.2	0.26	8509.51 (124; < 0.0001)	0.49	98.5	***< 0.001***
2011–2015	67,743	19.09	0.16	0.23	11498.52 (114; < 0.0001)	0.77	99	
1990–2000	2,415	30.72	0.2	0.48	527.44 (11; < 0.0001)	0.58	97.9	
2016–2020	7,794	31.34	0.26	0.38	2538.89 (27; < 0.0001)	0.25	98.9	
Sample size								
< 100	7,815	38.76	0.36	0.42	2764.17 (140; < 0.0001)	0.19	94.9	
> 500	87,225	7.93	0.06	0.1	13820.14 (57; < 0.0001)	0.95	99.6	***< 0.001***
200–500	22,341	18.74	0.16	0.22	3811.55 (67; < 0.0001)	0.32	98.2	
100–200	9,301	35.03	0.32	0.39	3811.55 (67; < 0.0001)	0.16	98.2	
Populations type								
Non-obese	85,464	5.02	0.04	0.06	4362.76 (90; < 0.0001)	0.64	97.9	
Obese	34,890	43.2	0.41	0.46	7850.65 (210; < 0.0001)	0.18	97.3	***< 0.001***
Overweight	6,328	17.33	0.14	0.21	477.77 (34; < 0.0001)	0.28	92.9	

Italic bold represents that the difference of indicators in this line is statistically significant

NAFLD, Nonalcoholic fatty liver disease; NAFL, nonalcoholic fatty liver; NASH, non-alcoholic steatohepatitis; HRMS, high resolution mass spectrum; MRS, Magnetic Resonance Spectroscopy; ALT, Alanine aminotransferase

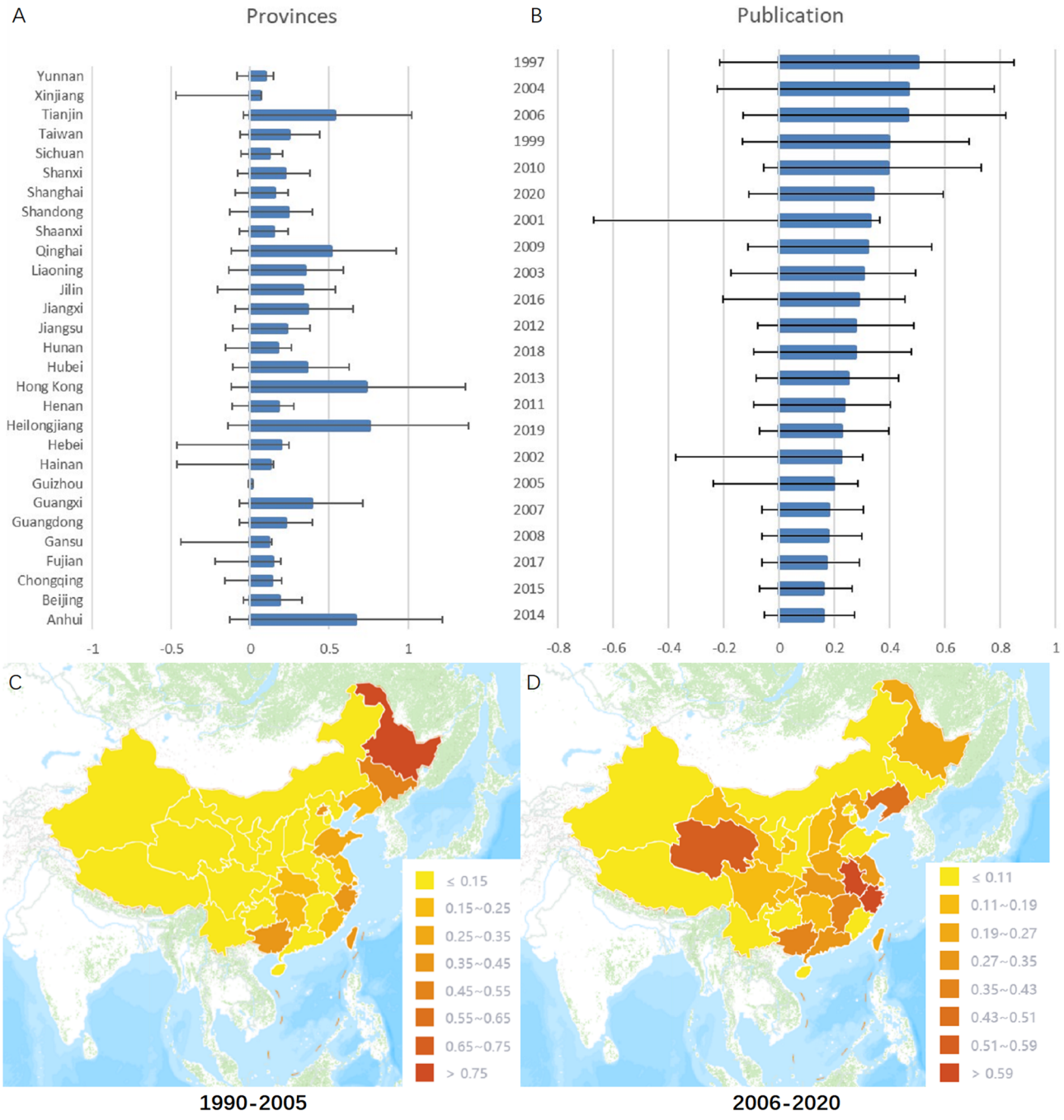


Fig. 2 The spatiotemporal distribution statistical map of pediatric NAFLD prevalence in China. Data are prevalence (95% CI) of NAFLD in different provinces (**A**). Data are prevalence (95% CI) of NAFLD in different year of publication (**B**). The prevalence of NAFLD in China from 1990 to 2005 (**C**), and from 2006 to 2020 (**D**), respectively. NAFLD, non-alcoholic fatty liver disease

Conversely, the prevalence in obese populations reaches 43.20%, exceeding the global mean of 34.2% [8]. Over the past decade, China has experienced a 12.25% increase in NAFLD prevalence, compared to a 5.5% increase in the United States during two decades [11]. The average NAFLD prevalence of 22.82% remains lower than adult rates in China [7].

Among the analyzed studies, only 24 reported NASH, with a notable absence of liver biopsy reports in the included studies for NASH identification. The diagnosis of NASH followed the Expert Consensus on the Diagnosis and Treatment of Non-Alcoholic Fatty Liver Disease in Children (2018) [12]. This diagnostic approach has gained widespread acceptance in China due to its

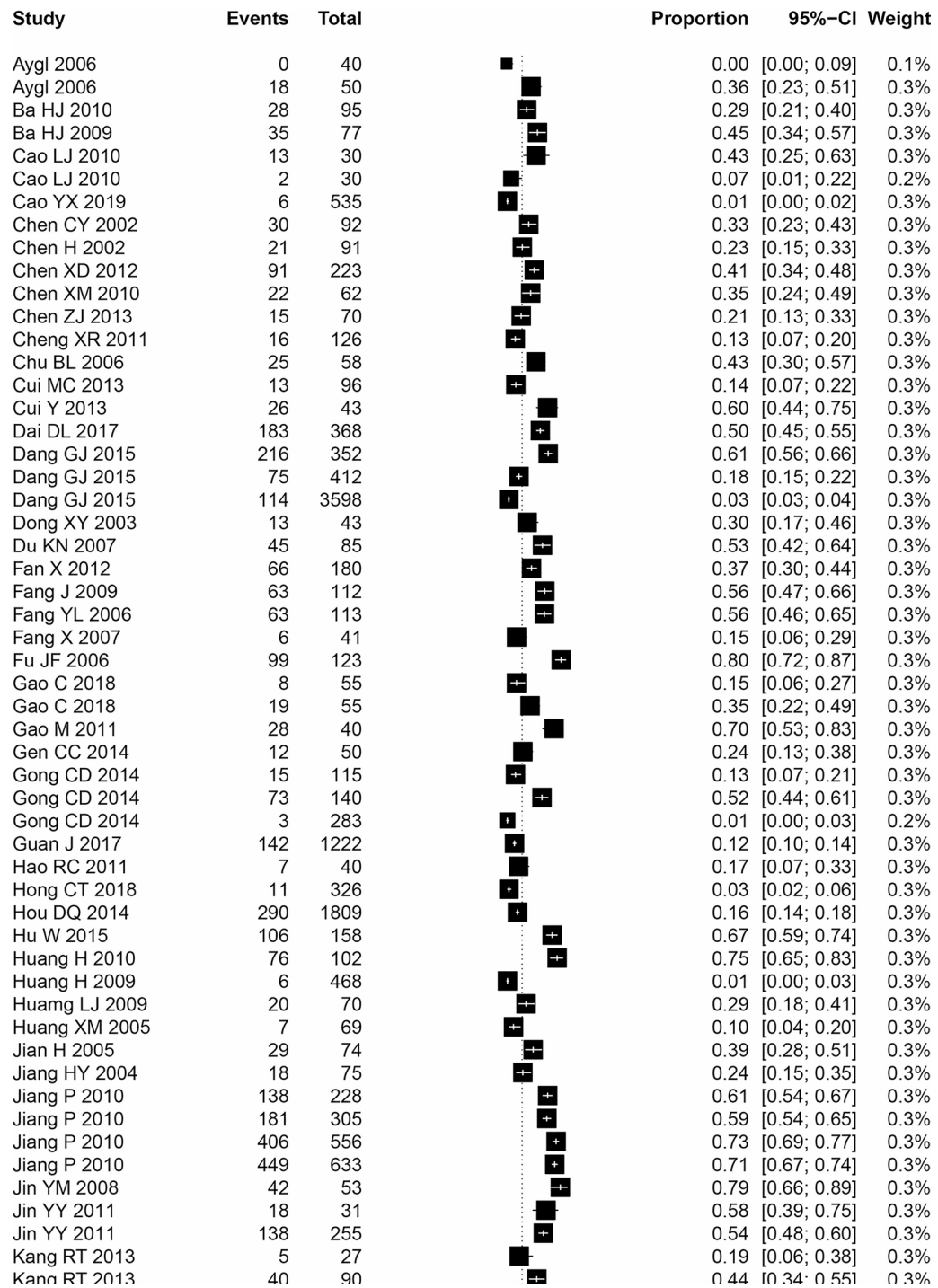


Fig. 3 Forest plot of the meta-analysis of prevalence of NAFLD. Each data marker represents a study, and the size of the data marker is proportional to the total number of individuals in that study. The summary effect size for each study is denoted by a diamond

economic feasibility and practicality. Furthermore, the World Gastroenterology Organization (WGO) global guidelines (2012), the European Association for the Study of the Liver (EASL) guidelines (2016), and the National Institute for Health and Care Excellence (NICE) guidelines (2016) recommend ultrasound and liver enzyme assessments for high-risk patients. The correlation between ALT and liver damage, as well as NASH activity, has been consistently demonstrated across multiple studies [13–15]. Nevertheless, current NASH detection methodologies in China require enhancement, with liver biopsy remaining the gold standard for NASH

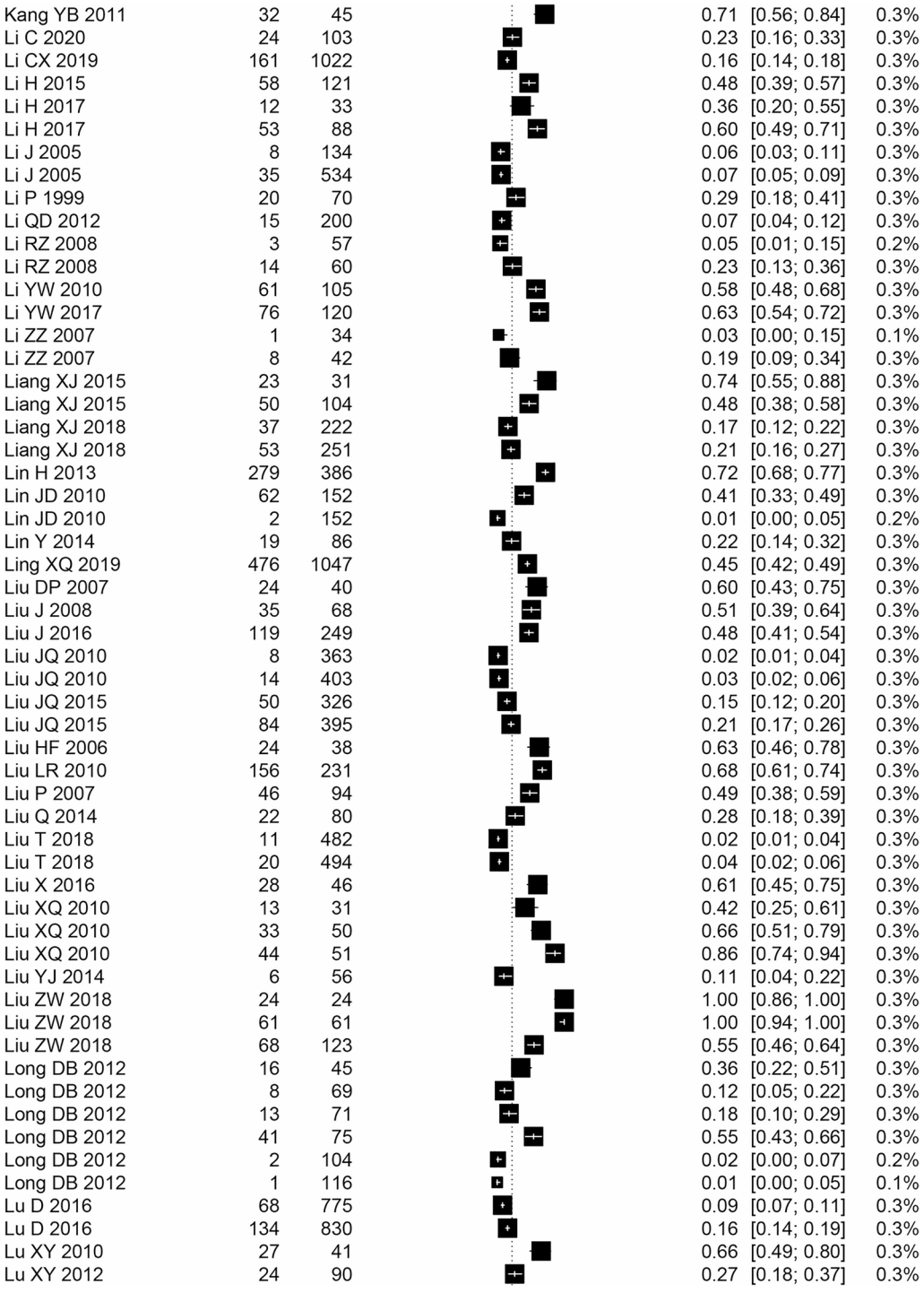
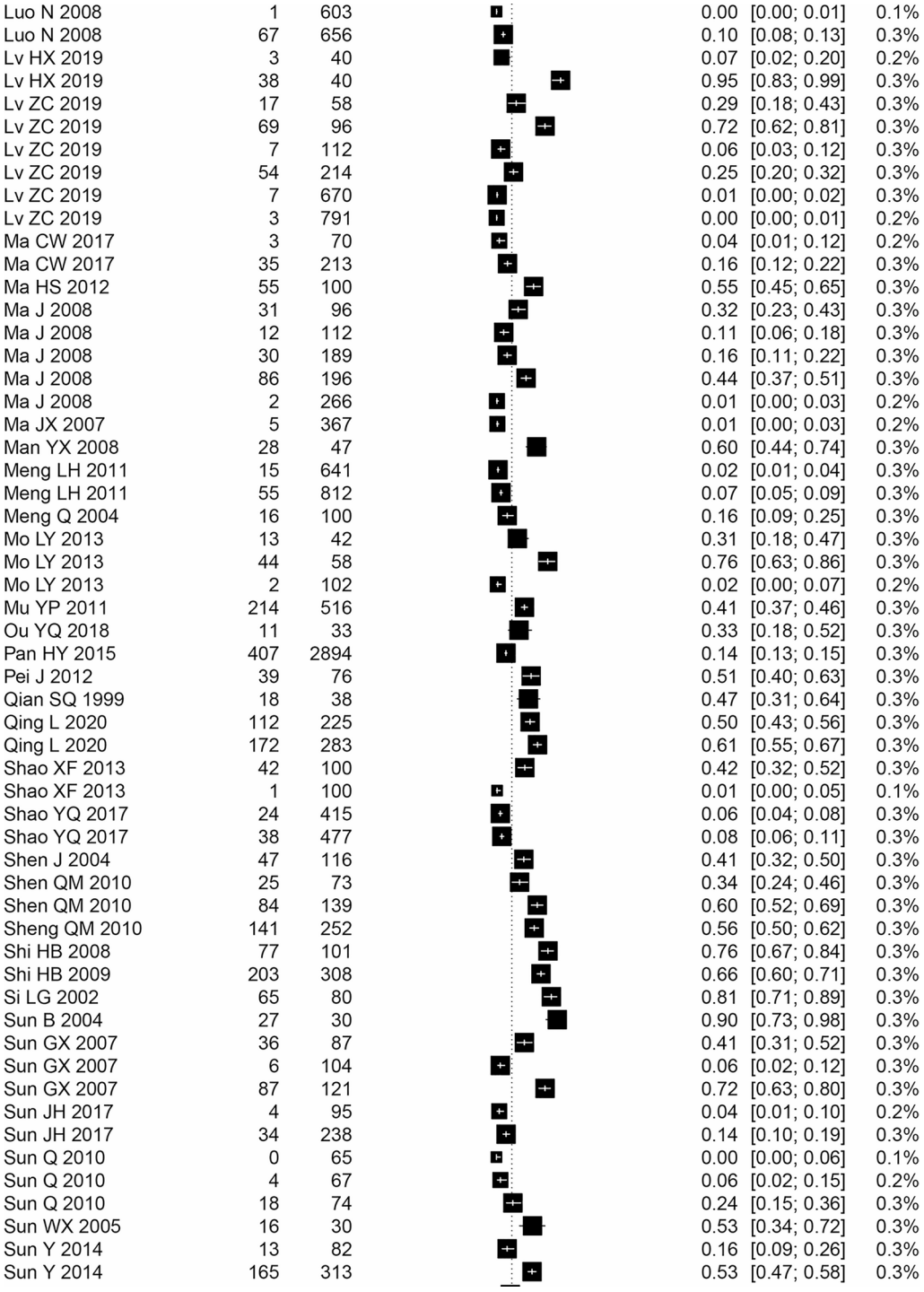


Fig. 3 (continued)

identification. Therefore, the findings regarding NASH in this study should be interpreted with appropriate caution. Additional biopsy-confirmed cases are necessary for future validation of these results.

Subgroup analysis reveals additional insights, confirming previous findings of higher NAFLD prevalence among older children, boys and obese individuals, aligning with global trends. Regional analysis indicates higher pediatric NAFLD prevalence in southern China compared to northern regions, contrasting with adult studies [7]. This disparity potentially correlates with southern China's advanced economic development, particularly in Hong Kong and Taiwan [16]. In northern China, northeast regions demonstrate higher prevalence than northwest



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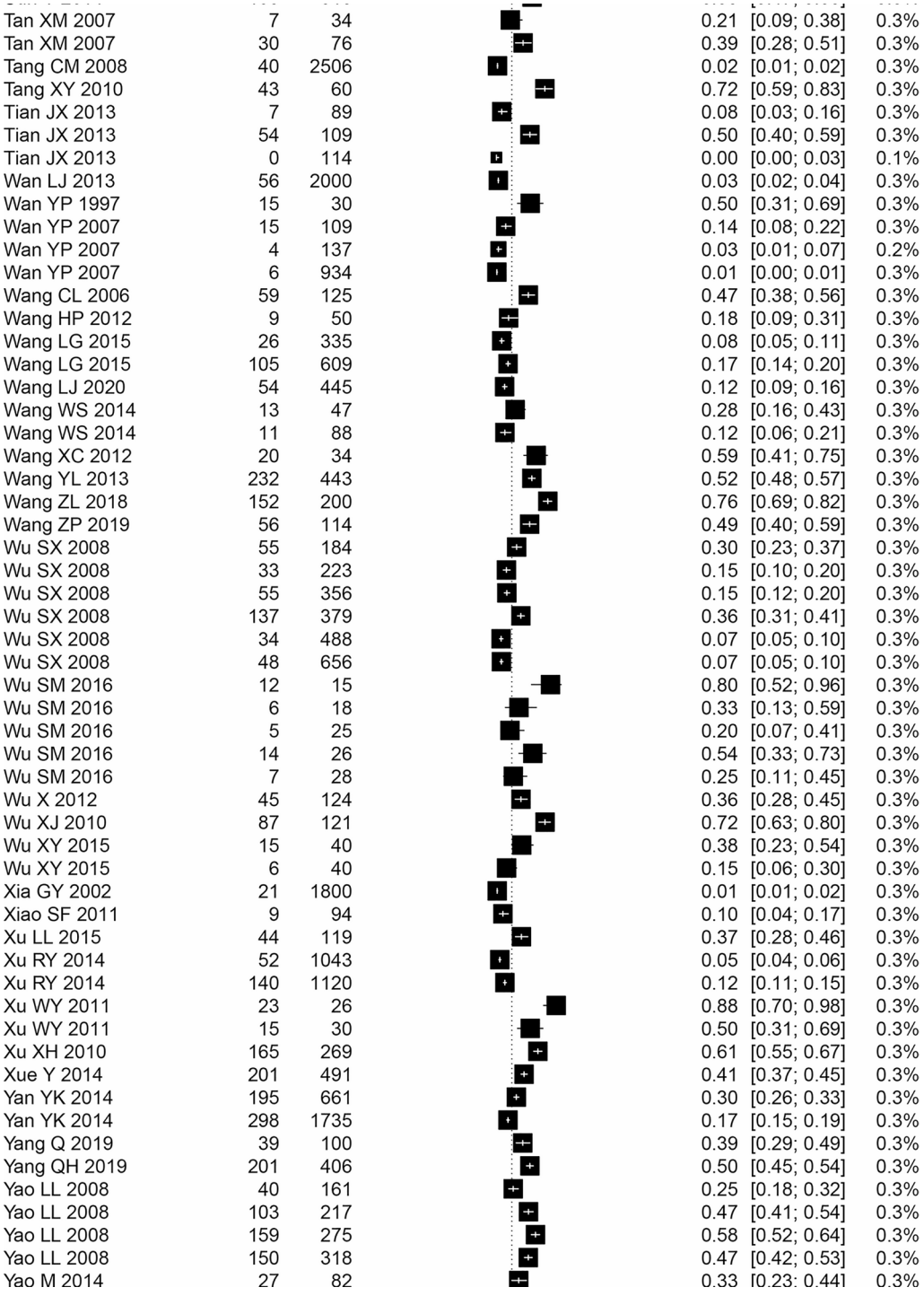
areas, possibly due to geographical factors. The elevated rates in Northeast China may be attributed to its plains location, as research indicates high altitude-induced hypoxia might improve mitochondrial function and activate AMPK signaling, potentially mitigating NAFLD [17]. Additionally, the cold climate reduces physical activity opportunities. The northwest's mountainous terrain may influence NAFLD progression through chronic mid-mountain hypoxia, with previous research noting lower BMI among NAFLD patients in middle mountain regions compared to low mountain areas [18]. Further research is necessary to determine whether plains geography and economic development constitute independent risk factors for pediatric NAFLD.



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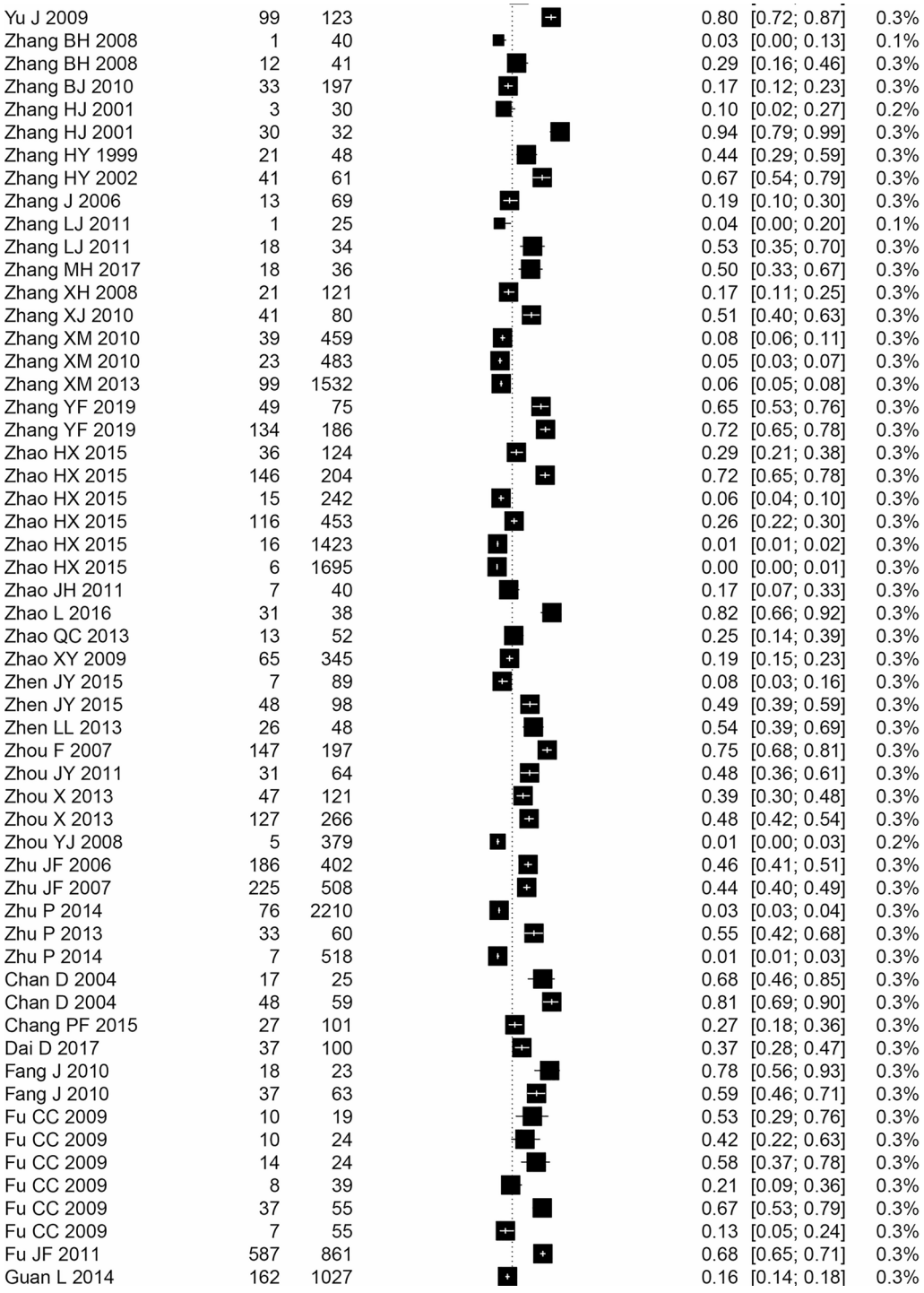
Diagnosis and biomarkers

Among diagnostic methods, HRMS or MRS, can accurately diagnose pediatric NAFLD [19]. However, HRMS and MRS are not recommended for routine clinical practice due to their high costs and limited availability. Ultrasound demonstrates limitations in detecting steatosis below 20% [20]. Regarding serum indicators, their sensitivity and specificity for identifying NAFLD remain lower than histological techniques. Specifically, ALT shows sensitivity of 64% and specificity of 81% in predicting pediatric NAFLD [21]. Given the inconsistencies between serological and imaging indicators, more sensitive diagnostic methods are required, particularly



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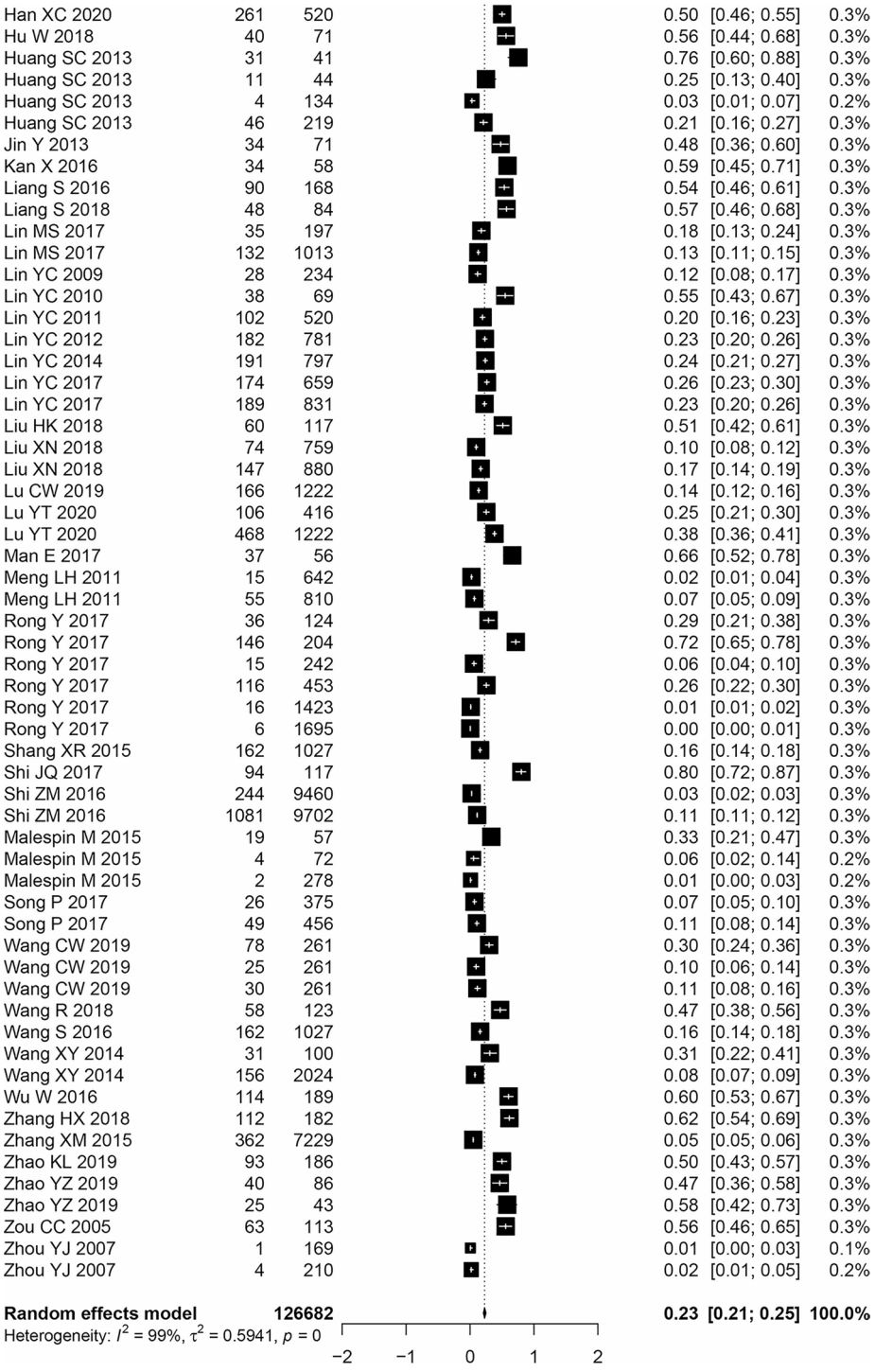
through the integration of machine learning and artificial intelligence to enhance NAFLD diagnosis in China [22].

Among metabolic risk factors, elevated BMI, WC, HOMA-IR, and WHR are significant risk factors for pediatric NAFLD. Consistent with previous studies, BMI has been identified as a risk factor for liver fibrosis in children, and BMI improvement correlates with reduced fibrosis [23, 24]. Beyond physical indicators suitable for screening, biomarkers demonstrate potential diagnostic value. Research indicates that HOMA-IR serves as an effective biomarker of NAFLD, and liver transcriptome signals related to HOMA-IR elucidate the early pathogenesis of NAFLD [25, 26]. HOMA-IR-related genes facilitate lipotoxicity, lipid metabolism disruption, and



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intrahepatic fat accumulation [27]. Regarding endocrine biomarkers, elevated ALT, AST, FINS, UA, LDL-C, TC, and TG predict progressive NAFLD, while increased HDL-C demonstrates protective effects. Several mathematical statistical models utilizing biomarkers for pediatric NAFLD prediction are currently under investigation [28–31]. These accessible biomarkers show promise as effective indicators for early NAFLD screening in children, particularly for large-scale school physical examinations.

Potential prevention measures

Regarding lifestyle and demographics, male gender and advanced age appear to contribute to NAFLD

Table 2 ANOVA analysis of NAFLD prevalence stratified by different subgroups

	Subgroup	Difference	95%CI		*p*
Severity	NAFL vs. NASH	0.030	−0.082	0.142	*0.599*
Gender	Boy vs. Girl	0.050	−0.092	−0.009	***0.018***
Surveillance model	Hospital-based vs. Population-based	−0.230	−0.268	−0.192	***0.000***
Area	North vs. South	0.050	0.010	0.090	***0.015***
Age	15–18 vs. 10–14	0.040	0.095	0.015	*0.208*
	15–18 vs. < 10	0.040	0.101	0.021	*0.272*
	10–14 vs. < 10	0.000	0.067	0.067	*0.995*
Region	Northwest vs. South China	0.130	−0.034	0.294	*0.224*
	Northwest vs. Northeast	0.280	0.021	0.539	***0.024***
	Northwest vs. Southwest	−0.040	−0.368	0.288	*1.000*
	Northwest vs. East China	0.130	0.028	0.232	***0.003***
	Northwest vs. North China	0.060	−0.057	0.177	*0.735*
	Northwest vs. Central China	0.080	−0.065	0.225	*0.664*
	South China vs. Northeast	0.150	−0.127	0.427	*0.684*
	South China vs. Southwest	−0.170	−0.512	0.172	*0.765*
	South China vs. East China	0.000	−0.141	0.141	*1.000*
	South China vs. North China	−0.070	−0.222	0.082	*0.823*
	South China vs. Central China	−0.050	−0.224	0.124	*0.980*
	Northeast vs. Southwest	−0.320	−0.716	0.076	*0.207*
	Northeast vs. East China	−0.150	−0.396	0.096	*0.548*
	Northeast vs. North China	−0.220	−0.472	0.032	*0.134*
	Northeast vs. Central China	−0.200	−0.466	0.066	*0.287*
	Southwest vs. East China	0.170	−0.147	0.487	*0.694*
	Southwest vs. North China	0.100	−0.222	0.422	*0.970*
	Southwest vs. Central China	0.120	−0.213	0.453	*0.939*
	East China vs. North China	−0.070	−0.152	0.012	*0.153*
	East China vs. Central China	−0.050	−0.169	0.069	*0.878*
	North China vs. Central China	0.020	−0.111	0.151	*0.999*
Income	Lower middle income vs. Middle income	0.020	0.085	0.045	*0.858*
	Lower middle income vs. Low income	0.060	0.541	0.661	*0.994*
	Lower middle income vs. High income	0.030	0.075	0.135	*0.883*
	Middle income vs. Low income	0.080	0.520	0.680	*0.986*
	Middle income vs. High income	0.050	0.044	0.144	*0.516*
	Low income vs. High income	0.030	0.635	0.575	*0.999*
Diagnostic	USS vs. ALT	0.150	0.215	0.085	***0.000***
	USS vs. HRMS	0.390	0.244	1.024	*0.390*
	USS vs. MRS	0.290	0.463	1.043	*0.756*
	ALT vs. HRMS	0.540	0.096	1.176	*0.129*
	ALT vs. MRS	0.440	0.315	1.195	*0.439*
	HRMS vs. MRS	0.100	1.083	0.883	*0.994*
Year	2001–2005 vs. 2006–2010	−0.060	−0.173	0.053	*0.600*
	2001–2005 vs. 2011–2015	−0.100	−0.209	0.009	*0.087*
	2001–2005 vs. 1990–2000	0.020	−0.208	0.248	*0.999*
	2001–2005 vs. 2016–2020	0.020	−0.132	0.172	*0.997*
	2006–2010 vs. 2011–2015	−0.040	−0.104	0.024	*0.427*
	2006–2010 vs. 1990–2000	0.080	−0.130	0.290	*0.838*
	2006–2010 vs. 2016–2020	0.080	−0.044	0.204	*0.401*
	2011–2015 vs. 1990–2000	0.120	−0.088	0.328	*0.513*
	2011–2015 vs. 2016–2020	0.120	0.000	0.240	***0.050***
	1990–2000 vs. 2016–2020	0.000	−0.234	0.234	*1.000*
Sample size	< 100 vs. > 500	−0.310	−0.394	−0.226	***0.000***
	< 100 vs. 200–500	−0.200	−0.293	−0.107	***0.000***
	< 100 vs. 100–200	−0.040	−0.149	0.069	*0.782*

Table 2 (continued)

	Subgroup	Difference	95%CI		*p*
	> 500 vs. 200–500	0.110	0.057	0.163	***0.000***
	> 500 vs. 100–200	0.270	0.193	0.348	***0.000***
	200–500 vs. 100–200	0.160	0.072	0.248	***0.000***
Population	Non-obese vs. Obese	0.380	0.354	0.406	***0.000***
	Non-obese vs. Overweight	0.120	0.067	0.173	***0.000***
	Obese vs. Overweight	−0.260	−0.316	−0.205	***0.000***

Italic bold represents that the difference of indicators in this line is statistically significant

NAFLD, Nonalcoholic fatty liver disease; NAFL, nonalcoholic fatty liver; NASH, non-alcoholic steatohepatitis; HRMS, high resolution mass spectrum; MRS, Magnetic Resonance Spectroscopy; ALT, Alanine aminotransferase

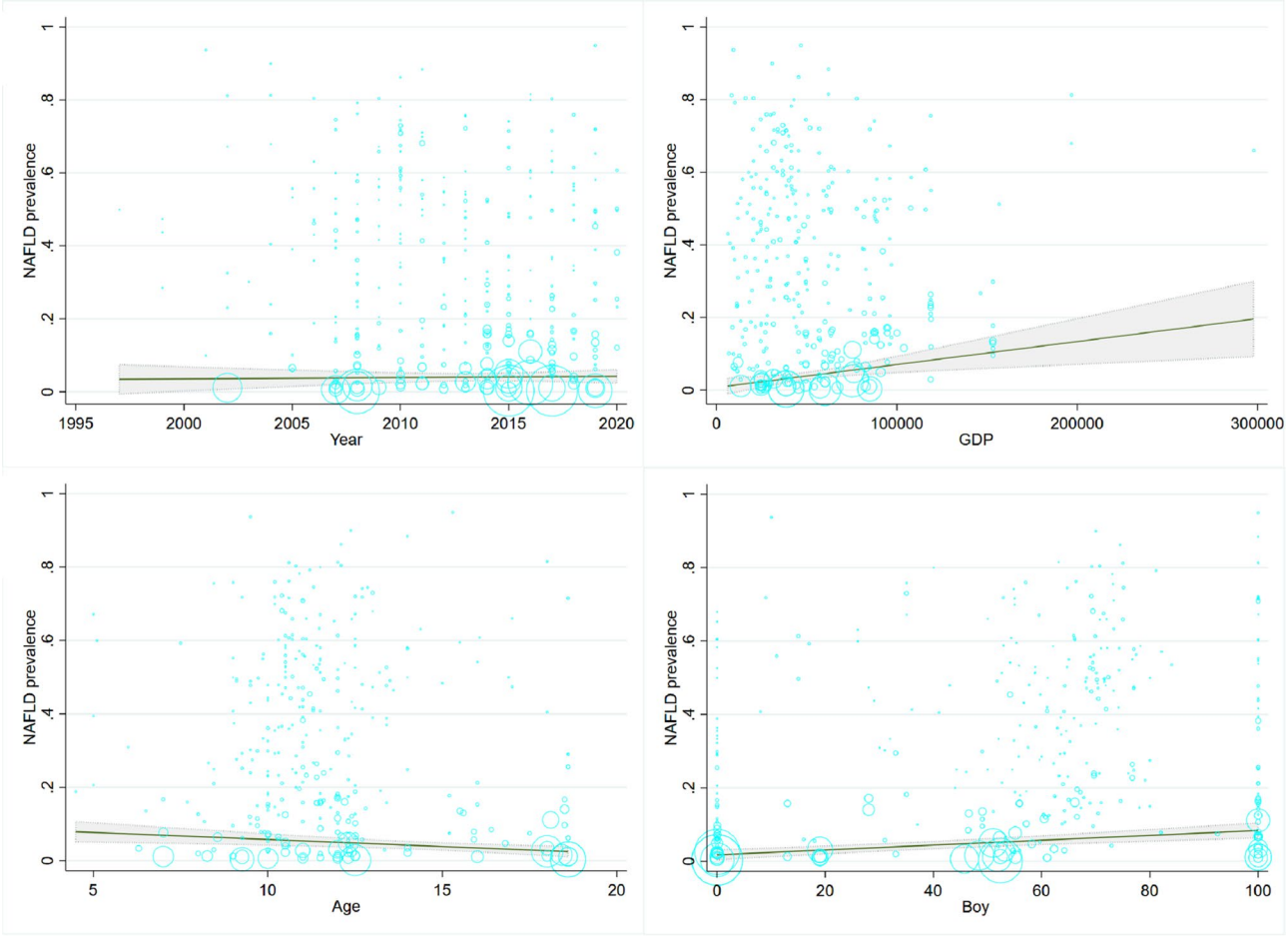

Fig. 4 Meta-regression of NAFLD prevalence stratified by different subgroups. Each data point overlaps into a circle. The size of a circle represents the weight of the corresponding data point, and the larger the circle, the greater the impact. GDP, Gross domestic product

development. Notably, this study revealed higher pediatric NAFLD prevalence among boys and older children. This pattern aligns with global pediatric NAFLD trends and adult NAFLD patterns in China [7, 8]. Furthermore, these findings indicate a greater disease burden of NAFLD among boys and older children. Future research must prioritize these specific populations and establish targeted prevention strategies.

Beyond lifestyle and demographics, molecular epidemiology suggests gene polymorphisms may correlate with pediatric NAFLD. Among genetic mutations, PNPLA3 rs738409, GCKR rs780094, and MTTP rs2306986 demonstrated associations with NAFLD susceptibility in children. Previous research indicates that PNPLA3 rs738409 promotes NAFLD development by activating specific fibrosis pathways through inflammation, altering lipid metabolism, and ultimately leading to fibrosis [32]. In NAFLD pathogenesis, MTTP rs2306986 facilitates disease progression by disrupting lipoprotein secretion and assembly, reducing fat output, and ultimately causing

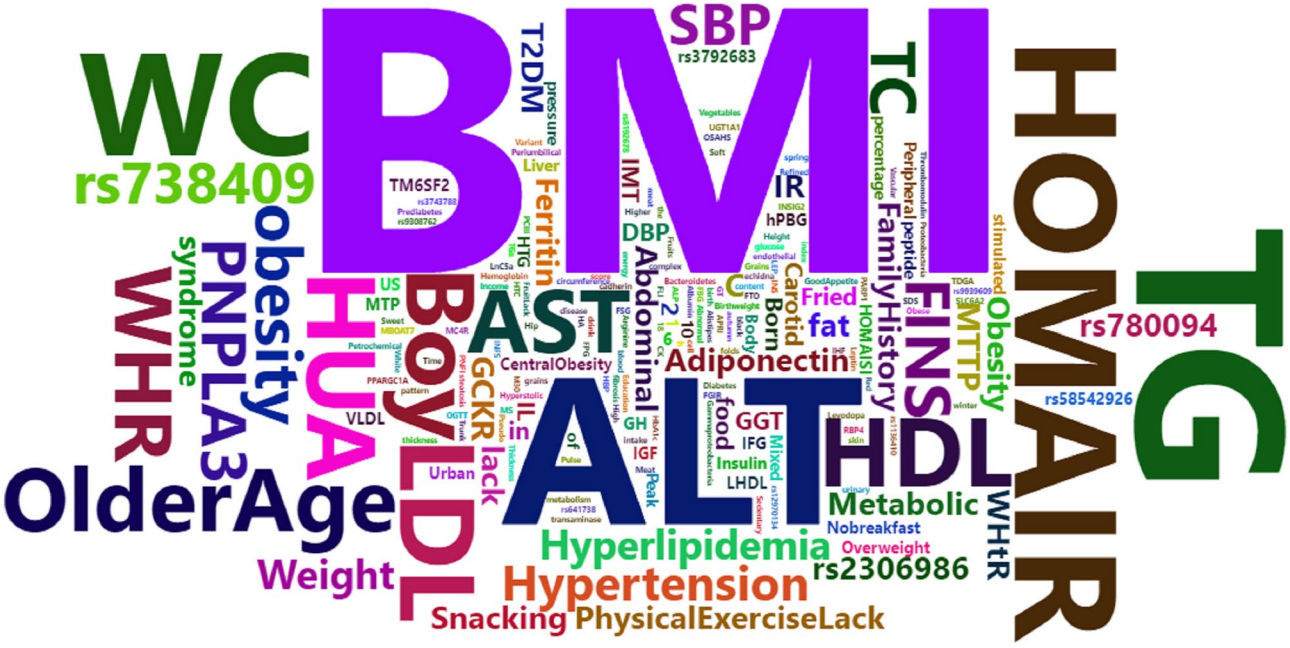

Fig. 5 Word cloud analysis of detailed epidemiological determinants of pediatric NAFLD. The larger the size of font, the higher the frequency of these determinants in different studies. OSAHS, Obstructive sleep apnea-hypopnea syndrome; MTP, Microsomal triglyceride transporter; PNPLA3, Patatin like phospholipase domain 3; WHR, Waist-to-hip ratio; UA, Uric acid; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; WC, Waist circumference; HUA, hyperuricemia; 2 h PBG, 2 h postprandial blood glucose; ALT, Alanine aminotransferase; AST, Aspartate aminotransferase; TG, Triglyceride; IMT, Intimal medial thickness; FINS, fasting insulin; WHtR, Waist-to-Height Ratio; IR, Insulin resistance; TC, Total cholesterol; FSG Fuctional specific gravity; NAFLD, non-alcoholic fatty liver disease

steatosis [33]. Studies demonstrate that GCKR rs780094 gene mutation may induce insulin resistance and metabolic disorders, subsequently leading to NAFLD in children [34]. Future research requires targeted interventions for children with NAFLD based on lifestyle and demographic factors. Additionally, development of targeted therapeutics based on gene polymorphisms warrants further investigation.

Strengths and limitations

This study presents several strengths and limitations. This comprehensive and current meta-analysis reveals the status of pediatric NAFLD prevalence in China. Significantly, various influencing factors in pediatric NAFLD prevalence were evaluated through subgroup analysis according to different groups of interest. The results demonstrated substantial heterogeneity, potentially attributable to geographical variations, diagnostic methodology, and population characteristics. Due to disparate health resource distribution in China, some less developed regions may lack comprehensive surveys of pediatric nonalcoholic fatty liver disease, resulting in incomplete data. Potential confounding factors, including dietary patterns and physical activity levels, may influence the pooled results. These confounding variables require consideration in future research. Although the overall sample size and results demonstrate good stability, the limited medical resources in the southwest region, represented by only four studies, may affect regional outcome stability. Consequently, future governmental initiatives should increase healthcare resource allocation to the southwest region, while pediatricians and researchers should direct additional attention to children's health in this area.

Conclusions

This study provides comprehensive information regarding pediatric NAFLD in China. The prevalence of pediatric NAFLD in China parallels global rates, though the growth rate remains comparatively high, suggesting an increased liver disease burden in China over coming decades. Future policies should emphasize prevention and control of NAFLD in children with elevated BMI, advanced age, and residence in southern regions. At the national level, enhanced awareness, research initiatives, and targeted health policies should be developed to control and prevent pediatric NAFLD.

Supplementary Information

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Supplementary Material 1

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Author contributions
XP: Methodology, Project administration, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Visualization, Writing-original draft. XT: Validation, Data curation, Writing-review & editing. JM: Validation, Data curation, Writing-review & editing. ACK: Formal analysis, Investigation, Resources, Data curation, Visualization, Writing-original draft. AL: Validation, Data curation, Writing-review & editing. KZ: Writing-review & editing. YP: Writing-review & editing. JQ: Validation, Data curation, Writing-review & editing. SP: Validation, Data curation, Writing-review & editing. HL: Validation, Data curation, Writing-review & editing.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Meta registration
The study protocol, with all relevant tools, is publicly available at PROSPERO, CRD42020206731.

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