Lipids in Health and Disease

REVIEW

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# Effectiveness of body roundness index for the prediction of nonalcoholic fatty liver disease: a systematic review and meta-analysis

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## Abstract

**Background** Several anthropometric indices, such as body mass index and waist circumference, have been used as clinical screening tools for the prediction of nonalcoholic fatty liver disease (NAFLD). To further refine these clinical tools for NAFLD, the body roundness index (BRI) has recently been evaluated. In this systematic review and meta-analysis, the objective was to evaluate the relationship and predictive capability of the BRI in identifying NAFLD.

**Methods** A comprehensive search was conducted in PubMed, Embase, Web of Science, and Scopus up to December 31, 2024. Eligibility criteria included observational studies on adults (≥ 18 years old) with measured BRI and its association with NAFLD. The Joanna Briggs Institute tool was used for risk of bias assessment. Meta-analyses used random-effects models to pool data on mean difference, odds ratio, sensitivity, specificity, and the area under the curve (AUC), with heterogeneity and publication bias assessed.

**Results** Ten studies involving 59,466 participants were included. The pooled mean difference in BRI between the NAFLD and non-NAFLD groups was 1.73 (95% confidence interval [CI]: 1.31–2.15). The pooled sensitivity and specificity of BRI for diagnosing NAFLD were 0.806 and 0.692, respectively. The pooled AUC for BRI was 0.803 (95% CI: 0.775–0.830), indicating good diagnostic accuracy. Unlike subgroup analysis by country, subgroup analysis by sex showed no significant differences. Higher BRI values were associated with increased odds of NAFLD (pooled OR = 2.87, 95% CI: 1.39; 5.96). Studies provided mixed results on the predictive ability of BRI compared to other indices like body mass index, mostly favoring BRI over conventional indices.

**Conclusion** BRI demonstrates a good diagnostic performance for NAFLD, suggesting it may be a valuable clinical tool for NAFLD assessment. Further research is necessary to validate these findings and strengthen the evidence base.

**Keywords** Nonalcoholic fatty liver disease, Body roundness index, Anthropometric index, Prediction

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## Introduction

Nonalcoholic fatty liver disease (NAFLD) is a condition characterized by the excessive accumulation of fat in the liver (histological presence of steatosis in more than 5% of hepatocytes) associated with insulin resistance in the absence of heavy alcohol consumption [1]. NAFLD comprises a range of histopathological conditions, including simple steatosis, nonalcoholic steatohepatitis (NASH), progressive cirrhosis, end-stage liver disease, and hepatocellular carcinoma (HCC) [2, 3]. Approximately 30.2% of the global population is affected by NAFLD, which has recently become the primary cause of chronic liver disease, surpassing viral hepatitis [4, 5]. NAFLD is a major public health issue because of its high prevalence as well as its close association with other public health issues such as metabolic syndrome, type 2 diabetes mellitus (T2DM), obesity, cardiovascular diseases, and dyslipidemia [6]. Recently, the nomenclature of NAFLD has been changed to metabolic dysfunction associated steatotic liver disease (MASLD) for a more precise reflection of its pathogenesis [7].

Non-invasive assessments, including medical history, laboratory testing, and imaging, are commonly employed for preemptive diagnoses [8]. NAFLD is typically diagnosed through abnormal liver function tests, such as increased alanine transaminase (ALT) and aspartate transaminase (AST), or by the incidental diagnosis of hepatic steatosis during radiologic abdominal imaging [8]. Imaging techniques such as computed tomography (CT) scans, abdominal ultrasound, or magnetic resonance imaging (MRI) can detect NAFLD but are not routinely used to differentiate between NAFLD subtypes [8]. Although liver biopsy is considered the gold standard for diagnosing NAFLD/NASH, its screening application is controversial due to associated risks and limitations such as variability in sampling error, observer variability, and high costs [9].

In 2013, Thomas DM and colleagues presented the body roundness index (BRI) as a predictor of visceral adiposity tissue and body fat percentage [10]. BRI has been found to effectively predict metabolic syndrome in men and women from various subgroups [11]. BRI offers potential advantages, such as incorporating both height and waist circumference (WC) to provide a more comprehensive estimate of body composition, which may better reflect visceral adiposity compared to body mass index (BMI) alone. However, its limitations include the need for further validation in diverse populations and the lack of clear evidence demonstrating its superiority over conventional biomarkers in all clinical contexts [12].

Recently, various studies have evaluated the BRI as a predictor of NAFLD and compared it with other anthropometric measures in the assessment of NAFLD risk. A study using data from a large cross-sectional survey found that participants with NAFLD had a higher BRI level compared to those in the non-NAFLD group, and the prevalence of NAFLD was found to have a positive association with BRI, regardless of age, gender, and BMI. Additionally, BRI outperformed other common anthropometric obesity-related measures, including BMI, WC, and a body shape index (ABSI), in assessing NAFLD risk [13]. Another population-based cross-sectional study discovered that BRI and waist-to-height ratio (WHtR) have stronger correlations with NAFLD compared to ABSI and waist-to-hip ratio (WHR) [14].

The findings indicate a significant association between the BRI and NAFLD, highlighting BRI's strong potential as a tool for NAFLD assessment. This systematic review and meta-analysis was conducted to explore the relationship between BRI and NAFLD, as well as its accuracy in predicting the disease.

## Method

### Study design

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15]. This systematic review and meta-analysis was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42024554538. The objective was to evaluate the association between BRI and NAFLD.

### Literature search

A comprehensive literature search was conducted across several databases, including PubMed, Embase, Web of Science, and Scopus, from their inception to December 31, 2024. The search strategy incorporated a combination of keywords and Medical Subject Headings (MeSH) terms related to BRI and NAFLD. The search query is provided in the Supplementary Table 1.

### Eligibility criteria

Studies were considered eligible if they met the following criteria: (1) Adults aged 18 years and older (with no upper age limit); (2) Studies that measured BRI (formula: $364.2 - 365.5 \times (1 - [(WC/2\pi)/(0.5 \times height)]^2)^{0.5}$ [10]) and evaluated its association and predictive power in diagnosing NAFLD; (3) Observational studies, including cross-sectional, cohort, and case-control studies; (4) Studies published in English.

Studies that were not peer-reviewed, conducted in languages other than English, on pediatric populations, and utilized animal models were excluded. Additionally, letters, commentaries, reviews, case reports, and case series were considered ineligible and, therefore, excluded from the systematic review.

After removing duplicates, SK and PF evaluated the titles and abstracts of all identified papers to determine eligibility based on the specified inclusion and exclusion criteria. Following the selection of studies that met these criteria, both authors independently performed a comprehensive review of the full texts. Any disagreements encountered during the review process were effectively resolved through consensus.

### Data extraction

Two independent reviewers (PF and SK) extracted data using a standardized data extraction form. The extracted data included study characteristics (i.e., author, year of publication, country, and study design), participant characteristics (sample size, mean age, age range, gender distribution), BRI measurement details, NAFLD diagnosis method and criteria, variables of adjustment, and statistical methods and results (e.g., means/medians, odds ratios [OR], hazard ratios, relative risk, incidence rate, area under the curve [AUC], sensitivity, specificity, confidence intervals [CI], standard deviation [SD]) from the most adjusted model. Discrepancies between reviewers were resolved through discussion or consultation with the third reviewer (AH).

### Quality assessment

As the study design of all included studies was cross-sectional, two reviewers (PF and AH) independently assessed the risk of bias in the included studies using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies (https://jbi.global/critical-appraisal-tools). This checklist evaluates the methodological quality of studies to ensure that their results are credible and relevant. The following domains were assessed: sampling and population, measurement of exposure and outcome, statistical analysis, completeness, and consistency. Eight questions were answered with "Yes", "No", "Unclear", or "Not applicable" to determine if the study is eligible to be included in this systematic review. Discrepancies between reviewers were resolved through consensus.

### Certainty of evidence

The certainty of evidence for each outcome was assessed using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) framework [16]. The overall quality of evidence for each outcome was categorized as high, moderate, low, or very low.

### Statistical analysis

The statistical analysis for this meta-analysis was conducted using R version 4.4 with the 'meta' and 'metafor' packages [17]. The primary outcomes of interest were the AUC, sensitivity, specificity, ORs (per unit increase), and mean differences (MDs) of the BRI in association with NAFLD. For each included study, AUCs, ORs, sensitivity, specificity, and MDs, along with their respective CIs or SDs (where available) were extracted. The ORs for each SD increment and each quartile were excluded from the meta-analysis because of inadequate data and varying quartile cut-offs, respectively. The methods developed by Wan et al. [18] and Luo et al. [19] were employed to convert median and interquartile range values into mean and standard deviation. In instances where the 95%CI for the AUC was not provided, the Hanley and McNeil (1982) [20] method was utilized to compute it. A random-effects model was used to pool data, which accounts for both within-study and between-study variability. Specifically, the restricted maximum likelihood (REML) method was employed for estimating the between-study variance ($\tau^2$). This model is particularly appropriate given the expected heterogeneity among the included studies. A bivariate diagnostic random-effects meta-analysis using the Reitsma model was conducted to estimate AUC based on the sensitivity and specificity values. Heterogeneity was assessed using the $I^2$ statistic and Cochran's Q test. A significance level of $p < 0.05$ was used to determine statistical significance throughout the analyses. An $I^2$ value greater than 50% or a significant Q test ($p < 0.10$) was considered indicative of substantial heterogeneity. Subgroup analyses were performed based on sex and country, where possible. Meta-regressions were conducted to explore sources of heterogeneity on BMI. Publication bias was evaluated using Egger's test [21] and visual inspection of funnel plots. Asymmetry in the funnel plots and a significant Egger's test ($p < 0.05$) were considered indicative of potential publication bias. Since some studies have reported their data only for subgroups, the number of evaluations for each analysis differs from the included studies.

## Results

### Literature search

The initial search yielded a total of 70 results, with 14 results from Embase, 16 from Web of Science, 17 from PubMed, and 23 from Scopus. After merging the results and removing duplicate entries, the number of unique studies was reduced to 23. These 23 studies were screened for eligibility based on their titles and abstracts, leading to the selection of 12 studies for a full-text review. Upon conducting a thorough full-text review of these 12 studies, two were excluded due to being non-English [22] and not reporting BRI [23]. Consequently, a total of ten studies were deemed eligible and were included in the qualitative synthesis for the meta-analysis. Figure 1 illustrates a flow diagram of study selection.

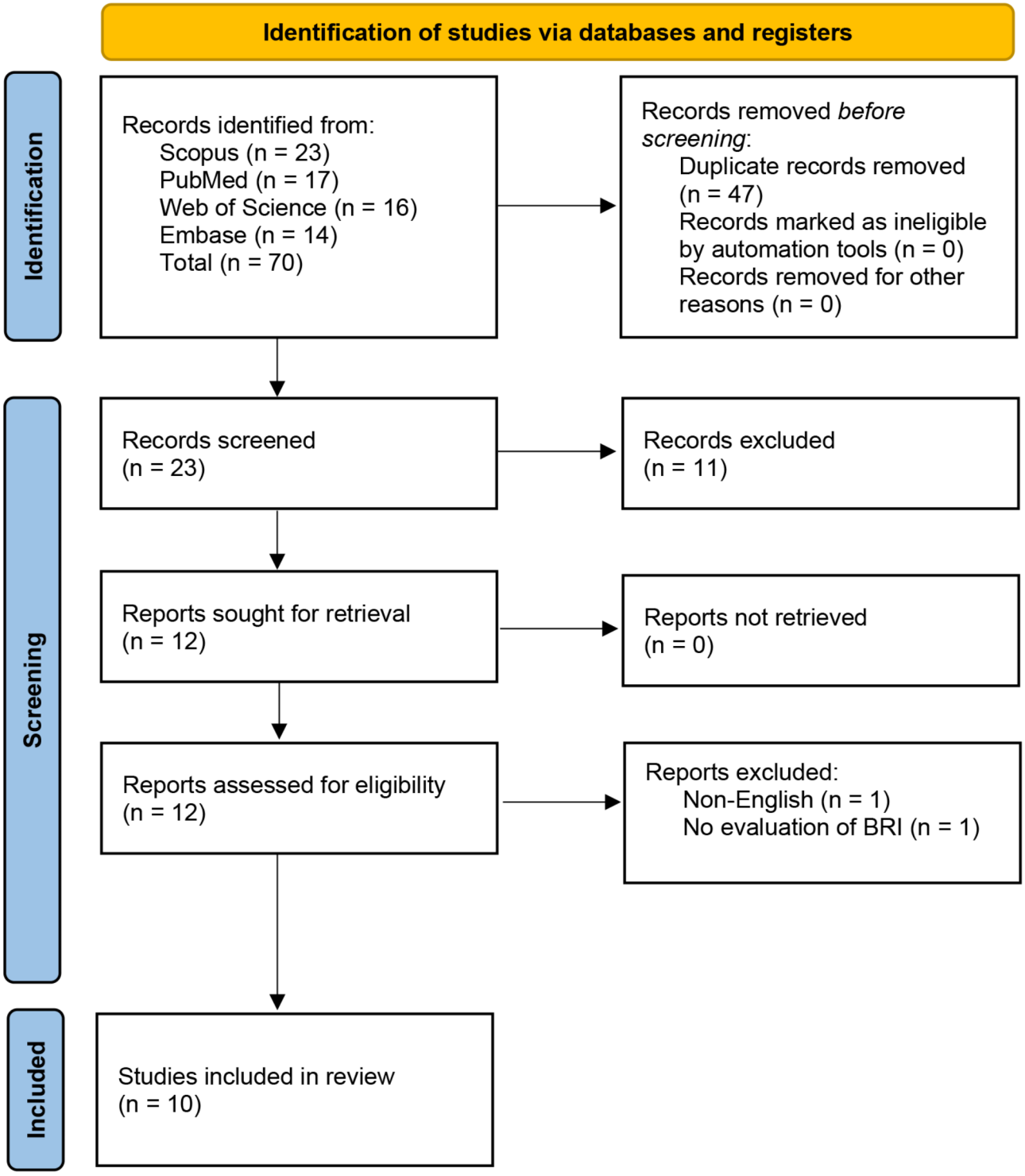


**Fig. 1** PRISMA flowchart illustrating the study selection process

### Study characteristics and risk of bias assessment

After assessing the risk of bias in the included studies based on the JBI tool, all studies were eligible to be included in the analyses (Supplementary Table 2). Based on GRADE, the majority of studies (8 out of 10) provided moderate-quality evidence, supporting strong recommendations for the association between exposure variables and outcomes in NAFLD patients. Two studies [24, 25] were rated as low-quality evidence due to serious limitations in risk of bias, supporting weak

recommendations. A consistent dose-response relationship was observed across multiple studies, with higher exposure levels associated with significantly increased odds of outcomes. Publication bias was undetected in all studies, and no significant issues with inconsistency, indirectness, or imprecision were identified in the majority of the evidence.

Overall, ten studies from countries including the USA ($n=4$), China ($n=2$), Japan ($n=1$), Taiwan ($n=1$), Italy ($n=1$), and Iran ($n=1$) were included. All studies had a cross-sectional design, and the total number of participants was 59,466. Transient elastography and ultrasound were used to diagnose NAFLD in four and six studies, respectively. The controlled attenuation parameter (CAP) cut-off in transient elastography varied from 248 to 274 dB/m. The summary of the basic characteristics of the included studies is shown in Table 1.

### Mean BRI in NAFLD vs. Non-NAFLD groups

The meta-analysis included a total of 14 evaluations of the association between BRI and NAFLD. The random effects model, which accounts for between-study variability, yielded a pooled MD of 1.73 (95% CI: 1.31–2.15, z = 8.10, $p<0.0001$). The analysis showed significant heterogeneity among the studies, as indicated by the $I^2$ statistic of 100% (Q = 58033.64, df = 13, $p<0.0001$) (Fig. 2).

In the female subgroup, which included five studies, the random effects model provided a pooled MD of 2.07 (95% CI: 1.42–2.73, z = 6.18, $p<0.0001$). The heterogeneity within the female subgroup was also significant, with the $I^2$ of 99.7% (95% CI: 99.7-99.8%), indicating substantial heterogeneity (Q = 1440.44, df = 4, $p<0.0001$). The male subgroup analysis, which also included five studies, showed a pooled MD of BRI of 1.42 (95% CI: 0.81–2.03, z = 4.55, $p<0.0001$). A significant heterogeneity was noted as $I^2$ = 99.9% (Q = 6546.70, df = 4, $p<0.0001$). A mixed-effects model was employed to compare the female and male subgroups. The results showed no statistically significant difference between male and female subgroups (estimated coefficient: -0.65, SE = 0.46, z = -1.43, $p=0.1538$, 95% CI: -1.55-0.24) (Fig. 2). A test for subgroup differences by country using the random effects model revealed significant variability between subgroups (Q = 75.88, df = 5, $p<0.0001$), indicating that the effect sizes varied significantly across countries (Supplementary Fig. 1).

A mixed-effects meta-regression model was conducted to examine the influence of BMI on the MDs. The model revealed a significant positive association between BMI and the effect size (β = 0.1994, SE = 0.0552, z = 3.6145, $p=0.0003$; 95% CI: 0.0913 to 0.3075). This suggests that higher BMI values were associated with larger MDs for BRI. The test for residual heterogeneity was significant (QE = 16,252.1517, df = 10, $p<0.0001$), indicating substantial unexplained variability (Supplementary Fig. 2).

### Diagnostic accuracy of BRI in NAFLD

#### *Sensitivity and specificity*

The meta-analysis included 11 evaluations of the sensitivity and specificity of the BRI in diagnosing NAFLD. The pooled sensitivity from the random-effects model was 0.806 (95% CI: 0.768–0.840), demonstrating significant heterogeneity ($I^2$ = 96%, $p<0.0001$). The pooled specificity from the random-effects model was 0.692 (95% CI: 0.668–0.716), also with significant heterogeneity ($I^2$ = 94%, $p<0.0001$) (Fig. 3).

The sensitivity analysis for the male subgroup included four studies, yielding a pooled sensitivity of 0.763 (95% CI: 0.694–0.822), with high heterogeneity ($I^2$ = 97%, $p<0.0001$). The sensitivity analysis for the female subgroup, also based on four studies, showed a pooled sensitivity of 0.852 (95% CI: 0.816–0.883), with substantial heterogeneity ($I^2$ = 83%, $p=0.0005$). For the male subgroup, the specificity analysis included four studies, resulting in a pooled specificity of 0.711 (95% CI: 0.678–0.742), with significant heterogeneity ($I^2$ = 91%, $p<0.0001$). The specificity analysis for the female subgroup, also based on four studies, showed a pooled specificity of 0.678 (95% CI: 0.622–0.729), with significant heterogeneity ($I^2$ = 97%, $p<0.0001$) (Fig. 4).

Based on the Reitsma method, the estimated average sensitivity of the BRI in diagnosing NAFLD was 0.806, with a 95% CI between 0.765 and 0.841. The average false positive rate, or 1 - specificity, was calculated at 0.308, with a 95% CI ranging from 0.283 to 0.334. The AUC was 0.786, indicating good overall diagnostic accuracy of the BRI in identifying NAFLD. The partial AUC, adjusted for the observed false positive rates, was 0.801, further supporting the BRI's diagnostic utility. $I^2$ estimate based on the Holling sample size unadjusted approach ranged from 89.9 to 95.7%, indicating high heterogeneity. The plotted summary receiver operating characteristic (SROC) curve based on sensitivities and specificities is illustrated in Fig. 5.

#### *The area under the curve*

The meta-analysis included 14 evaluations assessing the diagnostic accuracy of the BRI for diagnosing NAFLD. The random effects model revealed a pooled AUC of 0.803 (95% CI: 0.775–0.830, z = 57.16, $p<0.0001$), indicating a good diagnostic performance. There was significant heterogeneity among the studies (Q = 348.24, df = 13, $p<0.0001$), with an $I^2$ value of 96% (Fig. 6).

For the female subgroup, comprising five studies, the random effects model estimated the pooled AUC at 0.820 (95% CI: 0.771–0.868, z = 33.16, $p<0.0001$). The heterogeneity among these studies was significant (Q = 99.02,

**Table 1** Basic characteristics of the included studies

| Author, year | Country | Study design | Population | Age (age range) | Sample size (M%) | NAFLD (M%) | Non-NAFLD (M%) | Steatohepatitis diagnosis** | Adjustments |
|---|---|---|---|---|---|---|---|---|---|
| Jiang, 2023 [13] | USA | cross-sectional | general population | 44.8 ± 21.5 | 4467 (48.9%) | 1718 (54.0%) | 2749 (45.6%) | TE; CAP ≥ 274 dB/m | sex, age, race, BMI, diabetes, smoking status, alcohol use, education, uric acid, glycohemoglobin |
| Li, 2022 [27] | USA | cross-sectional | general population | 45.4 ± 0.64 (over 18) | 4195 (49.3%) | 2402 (44.6%) | 1793 (55.6%) | TE; CAP ≥ 274 dB/m | uric acid, lipid-lowering medication use, antihypertensive medication use |
| Lin, 2021 [24] | Taiwan | cross-sectional | general population | 54.9 ± 13.5 | 1969 (38.8%) | 826 (42.8%) | 1143 (35.9%) | ultrasound (at least 2 of the following: diffusely increased liver near-field ultrasound echo ("bright liver"), increased echogenicity in the liver compared to the kidneys, the gradual attenuation of a far-field ultrasound echo, and vascular blurring) | age, AST, ALT, TC, hemoglobin, eGFR, uric acid |
| Motamed, 2016 [14] | Iran | cross-sectional | general population | NAFLD: 48.61 ± 12.66 non-NAFLD: 39.04 ± 15.35 (18–74) | 4872 (55.9%) | 2048 (53.7%) | 2824 (57.4%) | ultrasound (evidence of hepatic steatosis) | age, TG, HDL-C, HOMA, MAP, the related obesity measures |
| Procino, 2019 [28] | Italy | cross-sectional | general population | F, NAFLD: 59.73 ± 12.96 M, NAFLD: 53.53 ± 13.56 F, non-NAFLD: 53.98 ± 15.74 M, non-NAFLD: 54.1 ± 15.51 | 2970 (56.5%) | 937 (69.5%) | 2033 (50.5%) | ultrasound | age, sex |
| Sheng, 2021 [30] | Japan | cross-sectional | general population | F: 43.27 M: 44.78 | 14,251 (52.0%) | 2507 (80.9%) | 11,744 (45.8%) | ultrasound (liver brightness (0–4 points), hepatorenal echo contrast (0–4 points), vascular blurring (0–1 points), and deep attenuation (0–2 points). If the final score is greater than or equal to 2 points, a diagnosis was made.) | age, habit of exercise, GGT, TC, HDL-C, HbA1c, smoking status, drinking status, DBP |
| Tian, 2023 [26]* | USA | cross-sectional | general population | NAFLD: 43.86 ± 1.34 non-NAFLD: 38.84 ± 1.1 | 8126 (NA) | 3617 (NA) | 4509 (NA) | TE; CAP ≥ 263 | NA |
| Wang, 2023 [29] | China | cross-sectional | general population | 46 (37–57) (18–75) | 12,658 (47.0%) | 6911 (61.9%) | 5747 (29.1%) | ultrasound with the presence of at least one of three criteria that includes overweight/obesity, type 2 diabetes, and clinical evidence of MetS | NA |

**Table 1** (continued)

| Author, year | Country | Study design | Population | Age (age range) | Sample size (M%) | NAFLD (M%) | Non-NAFLD (M%) | Steatohepatitis diagnosis** | Adjustments |
|---|---|---|---|---|---|---|---|---|---|
| Xie, 2021 [25] | China | cross-sectional | general population | NAFLD: 48.55 ± 14.21 non-NAFLD: 46.18 ± 14.74 (over 18) | 1748 (66.0%) | 526 (88.2%) | 1222 (56.4%) | ultrasound (two of the three following items: diffuse hyperechoic liver relative to kidney, ultrasound beam attenuation, and weakening visualization of intrahepatic structures.) | sex, age |
| Zhao, 2024 [54] | USA | cross-sectional | general population | over 20 | 4210 (NA) | 1187 (NA) | 3023 (NA) | TE; CAP ≥ 248 dB/m | sex, age, family poverty income ratio, diabetes, hypertension, hyperlipidemia, eGFR, ALT, AST, HDL-C, MetS |

Continuous variables were shown as mean ± SD or median (IQR)

General population: the entire group of individuals without any specific restrictions or exclusions based on comorbidities except for other causes of liver diseases

*Tian et al. [26] proposed two cutoffs for CAP, 263 and 285. Since the data for the 263 cutoff was complete, 263 was chosen in this analysis

** All studies excluded patients with evidence of other causes of liver diseases and hepatic steatosis (e.g. alcohol, viral hepatitis)

Abbreviations: ALT, Alanine aminotransferase; AST, Aspartate aminotransferase; BMI, body mass index; CAP, controlled attenuation parameter; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; F, females; GGT, Gamma-Glutamyl transferase; HbA1C, hemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; HOMA, homeostasis model assessment; M, males; MAP, mean arterial pressure; MetS, metabolic syndrome; NA, not available; NAFLD, non-alcoholic fatty liver disease; TC, total cholesterol; TE, transient elastography; TG, triglycerides

df = 4, $p < 0.0001$), with an $I^2$ value of 96%. The male subgroup analysis, also consisting of five studies, showed a pooled AUC of 0.781 (95% CI: 0.718 to 0.843, z = 24.42, $p < 0.0001$) under the random effects model. Significant heterogeneity was observed (Q = 109.47, df = 4, $p < 0.0001$), with an $I^2$ value of 96%. The comparison between the subgroups showed a difference of -0.04 (95% CI: -0.12-0.04, z = -0.94, $p = 0.3449$), indicating no significant difference in diagnostic performance between female and male subgroups (Fig. 6). Subgroup analysis using the random effects model revealed significant differences in AUC across countries (Q = 39.54, df = 5, $p < 0.0001$) (Supplementary Fig. 3).

A mixed-effects meta-regression model was conducted to examine the influence of BMI on AUC. The model revealed no significant association between BMI and AUC (β = -0.0010, SE = 0.0052, z = -0.1926, $p = 0.8472$; 95% CI: -0.0113 to 0.0093). This suggests that BMI did not significantly moderate the diagnostic accuracy of the BRI. The test for residual heterogeneity was significant (QE = 279.1841, df = 10, $p < 0.0001$) (Supplementary Fig. 4).

### Association of BRI with NAFLD

The meta-analysis incorporated data from 7 evaluations to evaluate the association between the BRI and the odds of NAFLD. The random effects model indicated a pooled OR of 2.8747 (95% CI: 1.3862; 5.9616, z = 2.84, $p = 0.0045$) for each unit increase in BRI, suggesting a statistically significant positive association between BRI and NAFLD. This result implies that higher BRI values are associated with increased odds of having NAFLD. Significant heterogeneity was present among the included studies (Q = 2620.33, df = 6, $p < 0.001$), with an $I^2$ value of 99.8%, indicating that a substantial portion of the observed variability is due to differences between the studies rather than random chance (Fig. 7).

In the study by Tian et al. [26], each quartile of BRI was compared to the first quartile regarding association with NAFLD, and their result showed the OR for the 4th quartile was 72.08 (95%CI: 48.66-106.77). Moreover, Xie et al. [25] showed that the OR for the 4th quartile was 50.41 (28.71, 88.53) compared to the first quartile (Table 2).

### BRI in different subgroups and comparison of BRI with other indices

Jiang et al. [13] found that the association between BRI and NAFLD differs with race, and the strongest association is seen in Hispanics (OR: 1.71; 95%CI: 1.22–2.39), excluding Mexican Americans. In the study by Motamed et al., BRI (OR = 5.484 for males and OR = 3.482 for females) and WHtR (OR = 5.309 for males and OR = 3.854 for females) had a stronger association with NAFLD compared to ABSI (OR = 1.363 for males and OR = 1.003 for females) and WHR (OR = 3.123 for females and OR = 1.628 for females) (Table 2) [14].

Two studies showed that the strongest association between BRI and NAFLD was seen in normal weight (OR: 1.77; 95%CI: 1.39–2.24 in Jiang study, OR: 8.32; 95%CI: 4.27–16.20 in Li study) compared to overweight

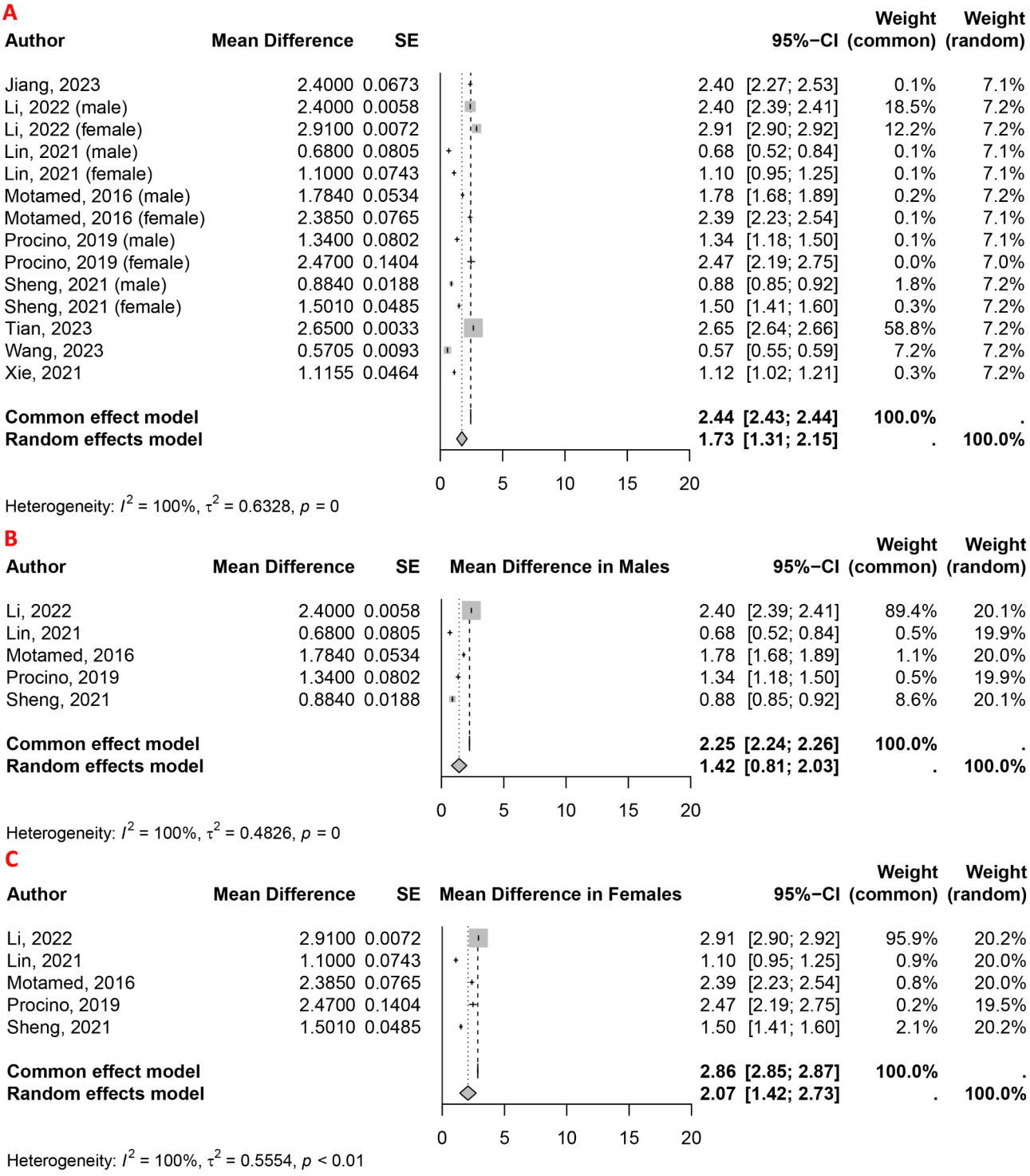


**Fig. 2** Pooled mean differences in BRI Between NAFLD and non-NAFLD groups: (**A**) overall population, (**B**) male subgroup, and (**C**) female subgroup

and obese groups (OR: 2.49; 95%CI: 2.17–2.86 in Li study, OR: 1.69 in overweight group and 1.29 obese group in Jiang study) (Table 2) [13, 27].

Results regarding the comparison of predictive ability in identifying NAFLD were controversial. Jiang et al. [13] found that BRI (AUC = 0.807) had a higher predictive ability in identifying NAFLD, compared with BMI (AUC = 0.796), WC (AUC = 0.686), and ABSI (AUC = 0.641). Also, Tian et al. showed that BRI (AUC = 0.8268) and abdominal volume index (AVI) (AUC = 0.8353) had better diagnostic ability for NAFLD than BMI (AUC = 0.8126) [26]. Also, based on the results

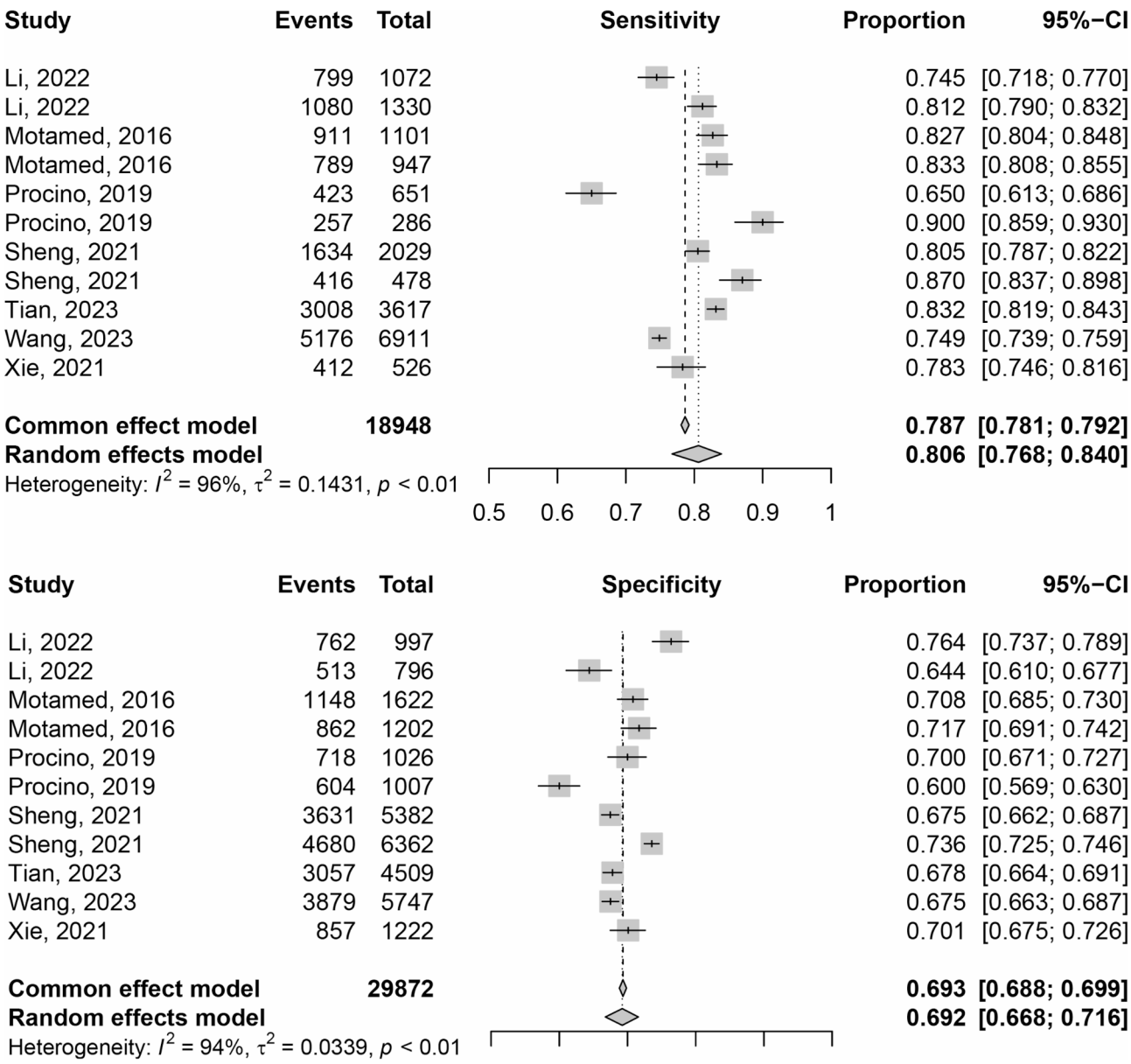


**Fig. 3** Pooled sensitivity and specificity of BRI for diagnosing NAFLD in the total population

of Procino et al. BRI was a better NAFLD predictor than BMI, but the AUROC was wider for the hepatic steatosis index (HSI) and FLI than other indices [28]. In contrast, the results of Xie et al. demonstrated that in total, BMI (AUC = 0.841) had the highest predictive power for NAFLD among all the indices, followed by WC, AVI, and BRI (AUC = 0.817); however, after stratifying by sex, BRI was the best predictor of NAFLD in females (AUC = 0.849) [25]. Moreover, Wang et al. found that In NAFLD screening, BMI (AUC = 0.89; 95%CI: 0.883–0.894) had the highest accuracy, followed by lipid accumulation product (LAP) (AUC = 0.87; 95%CI: 0.863–0.874) [29]. Based on the study by Sheng et al., parameters associated with the triglyceride-glucose (TyG) index demonstrated the highest predictive capability, and BRI and BMI showed similar predictive power in diagnosing NAFLD [30]. Finally, in the study by Lin et al., HSI (AUC = 0.785), followed by LAP (AUC = 0.750), had the greatest AUC for identifying NAFLD among evaluated indices, and BMI (AUC = 0.718) was superior to BRI (AUC = 0.670) in this regard (Table 2).

### Publication bias

The assessment of publication bias was conducted using a linear regression test of funnel plot asymmetry, as described by Egger et al. (1997). The test result was not statistically significant (t = -1.44, df = 12, $p$ = 0.1752),

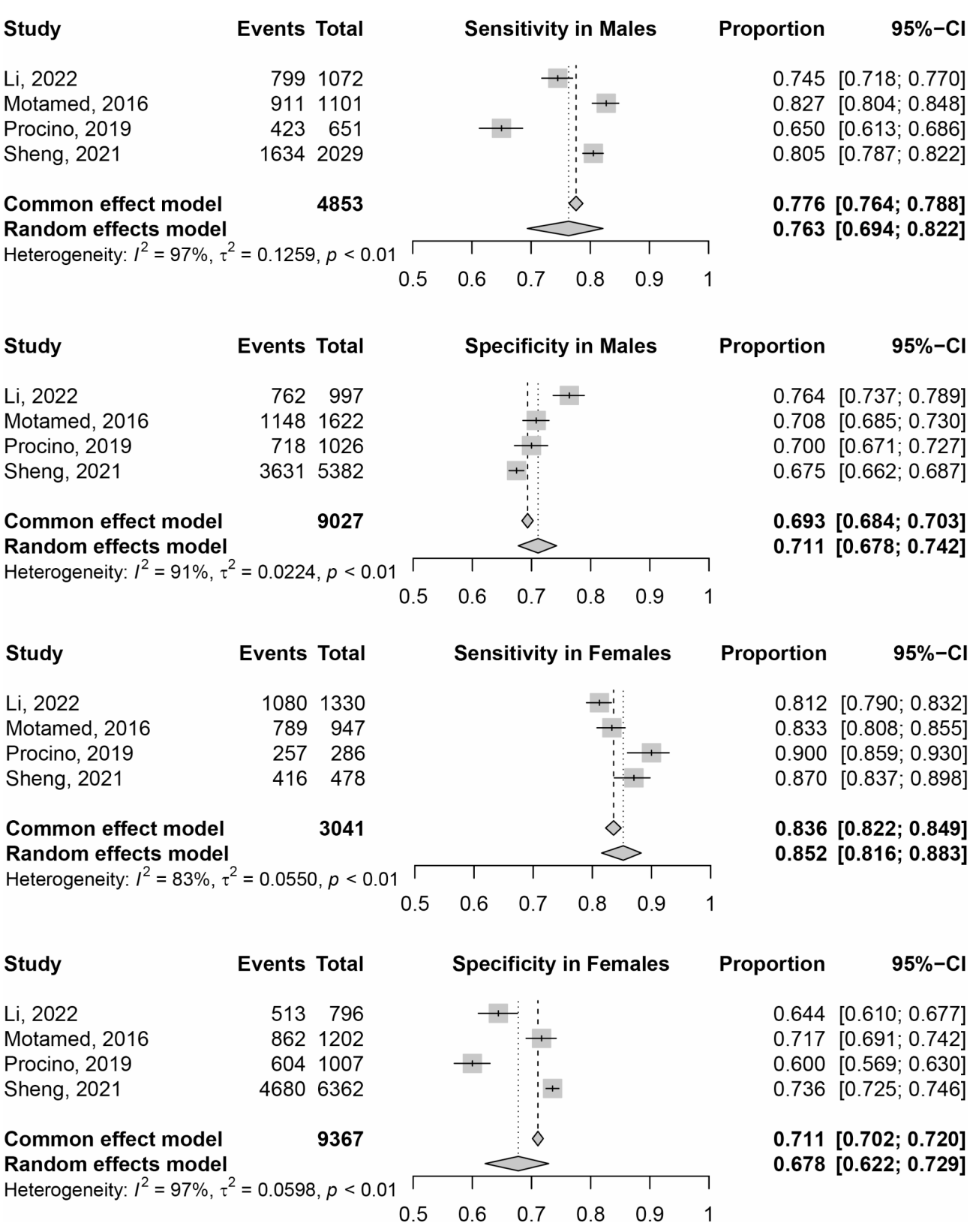


**Fig. 4** Pooled sensitivity and specificity of BRI for diagnosing NAFLD in male and female subgroups

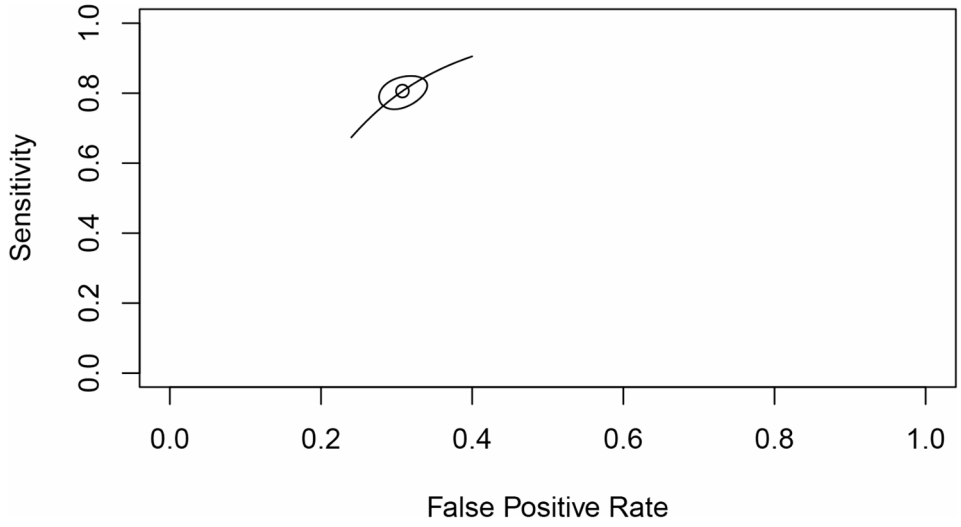


**Fig. 5** Summary receiver operating characteristic curve for BRI in the diagnosis of NAFLD

indicating no strong evidence of publication bias. The funnel plot is available in Supplementary Fig. 5.

## Discussion

The current meta-analysis, including data on more than 59,000 individuals, is the first to demonstrate that BRI, a new body composition metric, is a good predictor of NAFLD. The analysis revealed that BRI significantly correlated with NAFLD and had good discriminatory power for NAFLD, indicating its clinical usefulness for NAFLD assessment. Furthermore, higher BRI values were associated with increased odds of having NAFLD. Finally, there were no statistically significant differences between the male and female subgroups, indicating that the index can be used in all adults.

NAFLD is a chronic condition with an increasing trend in its prevalence. NAFLD develops gradually over the years, underscoring the significance of early diagnosis and intervention to prevent its progression to more advanced liver complications, such as cirrhosis and HCC [31]. The development of NAFLD is significantly impacted by the combined effects of low physical activity and a net positive energy balance. This imbalance, coupled with nutritional deficiencies and unhealthy diets, plays a crucial role in the progression of the disease. Calorie restriction, high-protein, or low-carbohydrate diets could improve hepatic steatosis in patients with NAFLD [32, 33].

Emerging evidence suggests that gut microbiota plays a significant role in the pathogenesis of NAFLD. Gut dysbiosis, characterized by an imbalance in microbial composition, has been linked to NAFLD development through mechanisms involving systemic inflammation, insulin resistance, and altered metabolic pathways [34, 35]. For instance, dysbiosis can lead to increased intestinal permeability, allowing endotoxins such as lipopolysaccharides to enter the bloodstream and trigger inflammatory responses that exacerbate hepatic steatosis and fibrosis [36]. Furthermore, gut microbiota influences energy metabolism and fat storage, which may indirectly affect BRI measurements by modulating visceral adiposity and body fat distribution [37].

Regular screening can result in the timely diagnosis and management of NAFLD in young individuals [38]. Although liver biopsy is the gold standard for diagnosing and grading NAFLD, however, it can not be used as a screening tool [39]. This is due to the limitations of biopsy, including its invasiveness, high cost, and limited availability [40]. Other tools for diagnosing and assessing NAFLD include imaging techniques such as ultrasound, transient elastography, and CT- and MRI-based scans. However, these methods are usually used for disease diagnosis and are not ideal for mass screening due to significant drawbacks, including high cost (CT and MRI scans), lack of safety (CT scans), lack of consensus (biomarker-based indices), limited accessibility (transient elastography, MRI scans), and complexity (MRI scans) [41, 42]. Non-invasive anthropometric measures offer significant advantages for the initial assessment, screening, and risk stratification of NAFLD, particularly in resource-limited settings. These tools are affordable, cost-effective, and easily implementable, making them valuable for facilitating early detection and identifying individuals at risk for NAFLD.

Anthropometric measures are non-invasive, easy to obtain, and inexpensive tools. Several non-invasive anthropometric measures, such as WC, WHtR, BMI, LAP, conicity index, and ABSI, have been studied in cardiovascular diseases and NAFLD and have provided valuable insights into assessing NAFLD risk and its

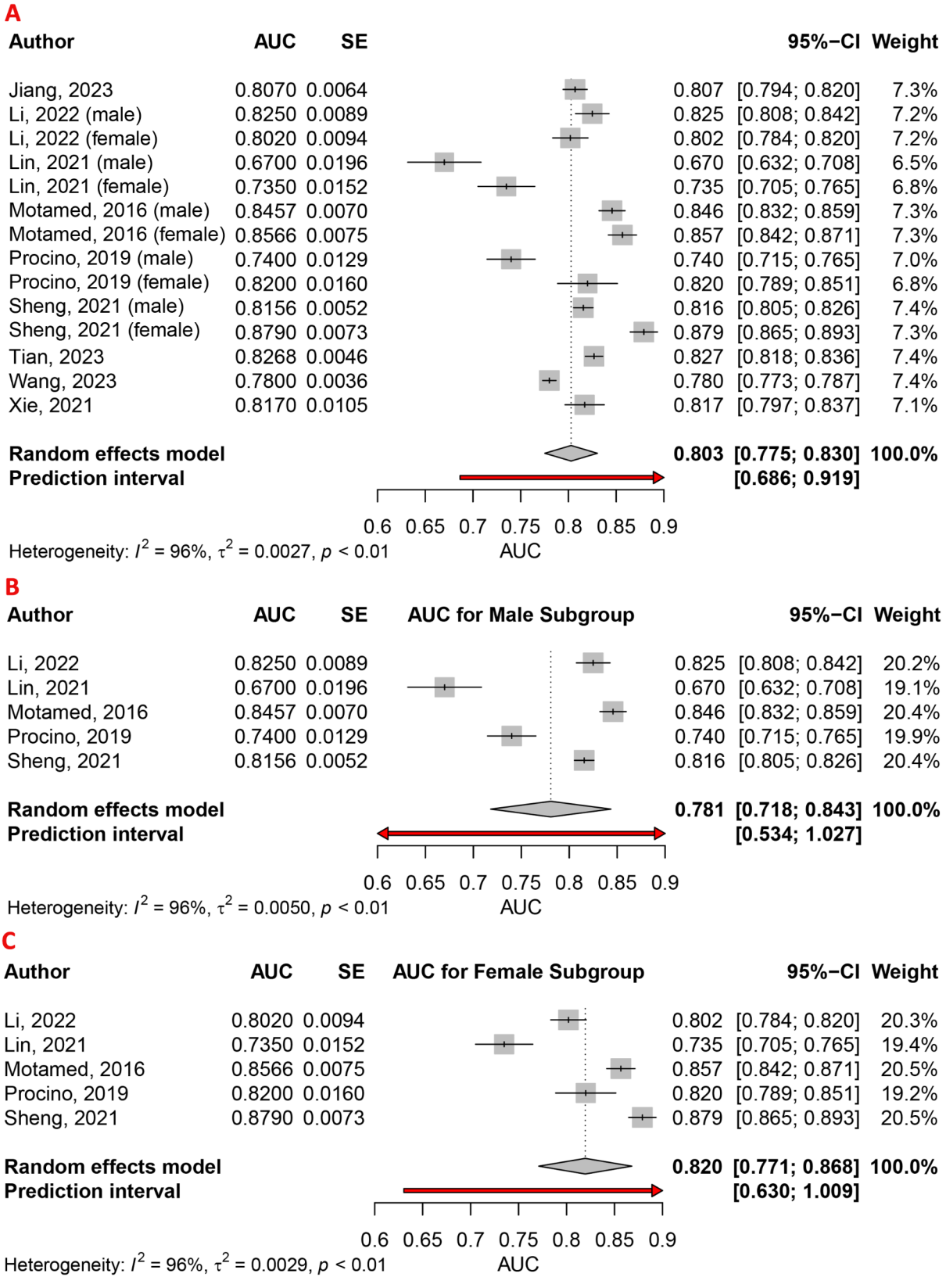


**Fig. 6** The pooled area under the curve (AUC) for BRI in diagnosing NAFLD: (**A**) total population, (**B**) male subgroup, and (**C**) female subgroup

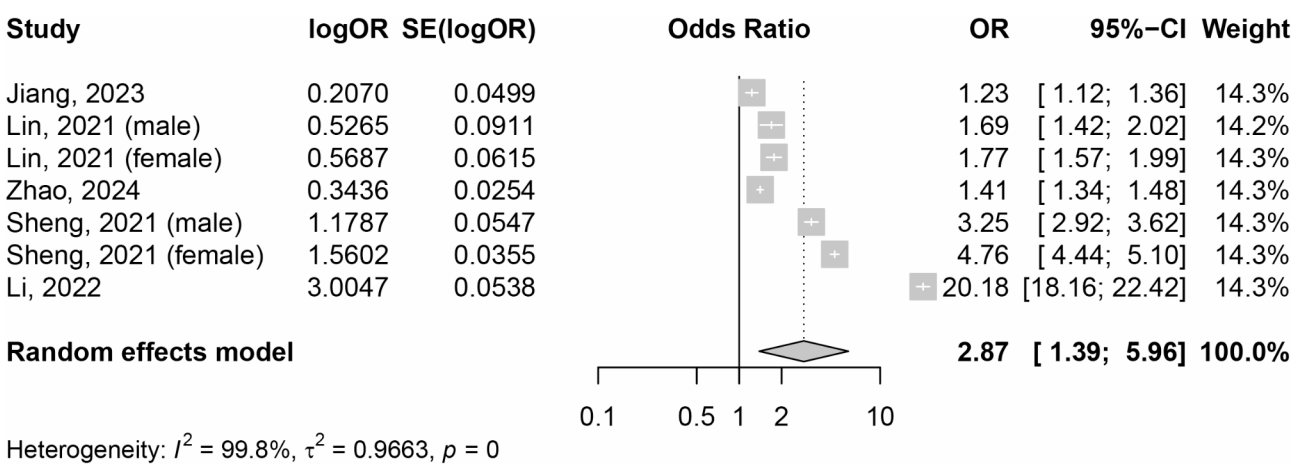


**Fig. 7** The pooled odds ratio (OR) for the association between BRI and NAFLD

screening [43, 44]. Easy-to-apply indicators for diagnosing hepatic steatosis are clinically important because they enhance early detection, improve diagnostic accuracy, are non-invasive and cost-effective, aid in risk stratification, reduce unnecessary procedures, and facilitate large-scale screening programs. BRI is a recently developed anthropometric measure designed to evaluate body shape and fat distribution. Unlike conventional obesity-related anthropometric indices such as BMI, which primarily consider weight and height, BRI incorporates additional body shape dimensions, including WC and height, to accurately evaluate obesity and its associated health risks [10]. BRI has a strong correlation with obesity, and higher BRI values are related to a greater accumulation of visceral fat [11]. It has been recognized as a reliable indicator for assessing NAFLD-associated conditions such as T2DM, insulin resistance, and metabolic syndrome [45, 46]. BRI also has significant discriminatory power for hypertension in adults from various populations. It proved to be a significantly better predictor of hypertension compared to ABSI and showed no significant difference compared to WC and WHtR in predicting hypertension [47]. BRI is also practical for detecting urate levels, hyperuricemia, and gout, highlighting the impact of central obesity on uric acid levels [48]. In the majority of studies included in this systematic review, the optimal BRI cut-off value for predicting NAFLD was found to be greater than 4. However, further research is necessary to establish a more precise and standardized BRI cut-off value for accurately predicting NAFLD.

The results of this study established that BRI is a valuable tool and a powerful predictor of NAFLD. The relationship between the BRI and NAFLD could be explained through several mechanisms. Primarily, BRI is associated with NAFLD because central obesity and metabolic disturbances lead to liver fat accumulation. Additionally, central obesity leads to fat accumulation in the liver due to systemic insulin resistance resulting from increased visceral fat. This insulin resistance impairs the liver's capability to metabolize free fatty acids [13]. Furthermore, visceral fat releases pro-inflammatory cytokines and adipokines, contributing to the development and progression of NAFLD [49].

In this study, BRI was also compared with other anthropometric indices. As expected, individuals with obesity are 3.5 times more likely to develop NAFLD, and there is a clear correlation between BMI and the risk of NAFLD [50]. However, among the indices studied, BMI is not a reliable, strong diagnostic tool for NAFLD. This could be because BMI does not consider body fat distribution, an essential factor in the onset of NAFLD [28]. In a recent systematic review and meta-analysis, WHtR was significantly higher in NAFLD patients than in the controls. The MD in WHtR between the two groups was 0.073 (95% CI 0.058–0.088), with an AUC of 0.815 (95% CI 0.780–0.849) for predicting NAFLD [51]. VAI is a newly studied scoring tool that showed significantly higher values in individuals with NAFLD compared to controls and in cases of severe steatosis compared to simple steatosis. Moreover, it was found that VAI can predict NAFLD with AUCs of 0.767 and 0.732, respectively [52]. A diagnostic test accuracy meta-analysis assessed the accuracy of LAP for screening NAFLD. The LAP index had a pooled sensitivity and specificity of 94% and 85%, respectively. In this study, the sROC curve initially showed an AUC of 0.95 (95% CI: 0.93–0.97), which decreased to 0.82 (95% CI: 0.79–0.85) in a second analysis, excluding the main source of heterogeneity [53]. Various factors, such as age, sex, comorbidities, and ethnicity, could influence the diagnostic accuracy of anthropometric indices.

**Table 2** Association of BRI with NAFLD

| Author, year | BRI | OR (95% CI) | AUC | Sensitivity | Specificity | Other findings |
|---|---|---|---|---|---|---|
| Jiang, 2023 [13] | Total: 5.2 ± 2.4<br>NAFLD: 6.7 ± 2.3<br>Non-NAFLD: 4.3 ± 2.0 | Total (per unit): 1.23 (1.11–1.35)<br>F: 1.15 (1.02–1.29)<br>M: 1.38 (1.17–1.64)<br>Q1 (1.04–3.45): reference<br>Q2 (3.46–4.91): 2.85 (2.06–3.95)<br>Q3 (4.91–6.59): 5.98 (4.16–8.60)<br>Q4 (6.59–19.10): 7.05 (4.42–11.23) | 0.807 | NA | NA | A stronger association between BRI and NAFLD was seen in males compared to females.<br>BRI had a higher predictive ability in identifying NAFLD, compared with BMI, WC, and ABSI.<br>Among races, the strongest association between BRI and NAFLD was seen in Hispanics, excluding Mexican Americans.<br>When stratified by BMI, the strongest association between BRI and NAFLD was seen in normal weight compared to overweight and obese groups. |
| Li, 2022 [27] | Total: 5.55 ± 0.11<br>F, MAFLD: 7.73 ± 0.2 F, non-NAFLD: 4.82 ± 0.13<br>M, MAFLD: 6.53 ± 0.16<br>M, non-NAFLD: 4.13 ± 0.10 | per SD: 2.22 (2.00-2.47) | Total: 0.799 (0.786–0.812)<br>F: 0.802 (0.784–0.821)<br>M: 0.825 (0.808–0.843) | Total: 79.90%<br>F: 81.20%<br>M: 74.50% | Total: 66.70%<br>F: 64.40%<br>M: 76.40% | A stronger association between BRI and NAFLD was seen in males compared to females.<br>A stronger association between BRI and NAFLD was seen in subjects with BMI < 25 compared to BMI ≥ 25.<br>A stronger association between BRI and NAFLD was seen in subjects without abdominal obesity compared to subjects with abdominal obesity. |
| Lin, 2021 [24] | F, NAFLD: 4.41 ± 1.27<br>F, non-NAFLD: 3.31 ± 1.24<br>M, NAFLD: 4.35 ± 1.11<br>M, non-NAFLD: 3.67 ± 1.11 | F (per unit): 1.766 (1.565–1.992)<br>M (per unit): 1.693 (1.416–2.024) | F: 0.735<br>M: 0.670 | NA | NA | HSI had the greatest AUC compared to LAP, BMI, AVI, VAI, TyG, WHtR, BRI, BAI, WHR, and conicity index. |
| Motamed, 2016 [14] | F, NAFLD: 6.618 ± 1.806<br>F, non-NAFLD: 4.233 ± 1.704<br>M, NAFLD: 5.201 ± 1.402<br>M, non-NAFLD: 3.417 ± 1.312 | F: 3.482 (2.973–4.077)<br>M: 5.484 (4.572–6.577) | F: 0.8566 (0.8419–0.8714)<br>M: 0.8457 (0.8320–0.8593) | F: 83.30%<br>M: 82.70% | F: 71.70%<br>M: 70.80% | BRI and WHtR have strong a association with NAFLD.<br>ABSI and WHR have a weaker association with NAFLD than BRI and WHtR. |
| Procino, 2019 [28] | F, NAFLD: 6.8 ± 2.16<br>F, non-NAFLD: 4.33 ± 1.85<br>M, NAFLD: 5.96 ± 1.7<br>M, non-NAFLD: 4.62 ± 1.43 | NA | F: 0.82<br>M: 0.74<br>F, age-adjusted: 0.8<br>M, age-adjusted: 0.76 | F: 90%<br>M: 65% | F: 60%<br>M: 70% | FLI showed the best AUROC and BMI showed the worst among FLI, HSI, BMI, WC, AVI, WHtR, WHt_5R, and BRI. |
| Sheng, 2021 [30] | F, NAFLD: 3.82 (3.21–4.61)<br>F, non-NAFLD: 2.33 (1.88–2.92)<br>M, NAFLD: 3.42 (2.98–3.97)<br>M, non-NAFLD: 2.56 (2.12–3.04) | F (per SD): 2.58 (2.32–2.88)<br>M (per SD): 3.32 (2.80–3.22) | F: 0.8790 (0.8647–0.8932)<br>M: 0.8156 (0.8054–0.8257) | F: 87.03%<br>M: 80.53% | F: 73.56%<br>M: 67.47% | NAFLD was strongly correlated with TyG-related parameters and HSI.<br>TyG-WC was the most strongly correlated index with NAFLD compared to BMI, WC, WHtR, TyG, TyG-BMI, TyG-WHtR, HSI, VAI, and LAP. |
| Tian, 2023 [26]* | NAFLD: 6.74 ± 0.17<br>Non-NAFLD: 4.09 ± 0.11 | Q1: reference<br>Q2: 7.95 (5.85–10.81)<br>Q3: 23.18 (17.91–30.01)<br>Q4: 72.08 (48.66-106.77) | Total: 0.8268<br>F: 0.8246 (0.8121–0.837)<br>M: 0.8517 (0.8402–0.8633) | Total: 83.16%<br>F: 83.02%<br>M: 79.35% | Total: 67.80%<br>F: 67.61%<br>M: 75.45% | BRI and AVI had better diagnostic ability for NAFLD than BMI. |
| Wang, 2023 [29] | Total: 4.12 (3.74–4.53)<br>NAFLD: 4.36 (4.04–4.77)<br>Non-NAFLD: 3.80 (3.49–4.17) | NA | Total: 0.78 (0.774–0.788)<br>F: 0.83 (0.827–0.845)<br>M: 0.73 (0.721–0.744) | Total: 74.90%<br>F: 80.30%<br>M: 73.80% | Total: 67.50%<br>F: 71.80%<br>M: 60.60% | In NAFLD screening among BMI, WC, WHtR, ABSI, BRI, VAI, and LAP, BMI had the highest accuracy, followed by LAP.<br>This study defined a high-risk population for MAFLD as follows: (1) BMI ≥ 23 kg/m2; and (2) BMI < 23 kg/m2 and LAP ≥ 20.75 |

**Table 2** (continued)

| Author, year | BRI | OR (95% CI) | AUC | Sensitivity | Specificity | Other findings |
|---|---|---|---|---|---|---|
| Xie, 2021 [25] | NAFLD: 4.36 (3.77-5.00)<br>Non-NAFLD: 3.22 (2.72–3.84)<br>F, NAFLD: 4.52 (4.11–5.01)<br>F, non-NAFLD: 21.6 (19.9–23.5)[Ψ]<br>M, NAFLD: 4.32 (3.73-5.00)<br>M, non-NAFLD: 3.24 (2.75–3.84) | Q1: reference<br>Q2: 5.49 (3.08–9.80)<br>Q3: 14.00 (8.00-24.47)<br>Q4: 50.41 (28.71–88.53) | Total: 0.817 (0.796–0.837)<br>F: 0.849 (0.804–0.894)<br>M: 0.812 (0.787–0.836) | 78.3% | 70.1% | Among WC, ABSI, AIP, AVI, BAI, BMI, BRI, CI, TyG, WHR, and WHtR, BMI showed the highest risk of NAFLD among all the indices, followed by WC and AVI.<br>BRI and BMI were the best predictors for NAFLD in males and BRI for predicting NAFLD in females. |
| Zhao, 2024 [54] | NA | per unit: 1.41 (1.34–1.48)<br>T1: reference<br>T2: 3.53 (2.73–4.57)<br>T3: 7.00 (5.29–9.27) | NA | NA | NA | The risk of NAFLD significantly increased at BRI values below 4.82, followed by a gradual rise in the curve. |

Continuous variables were shown as mean ± SD or median (IQR)

*Tian et al. [26] proposed two cutoffs for CAP, 263 and 285. Since the data for the 263 cutoff was complete, 263 was chosen in this analysis

Ψ It seems that this value was not accurately reported in the study of Xie et al. [25]

Abbreviations: ABSI, a body shape index; AIP, atherogenic index of plasma; AUC, area under the curve; AUROC, area under the receiver operating characteristic curve; AVI, abdominal volume index; BMI, body mass index; BRI, body roundness index; CI, confidence interval; F, Females; FLI, fatty liver index; HSI, hepatic steatosis index; LAP, lipid accumulation product; M, males; MAFLD, metabolic dysfunction-associated fatty liver disease; MAP, mean arterial pressure; NA, not available; OR, odds ratio; Q, quartile; SD, standard deviation; T, tertile; TyG-BMI, triglyceride glucose-body mass index; TyG-WC: triglyceride glucose-waist circumference; TyG, triglyceride-glucose index; TyG-WHtR, triglyceride-glucose waist-to-height ratio; VAI, visceral adiposity index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; WHt_5R, Waist/Height$^{0.5}$

## Strengths and limitations

In the available literature, this study is the first systematic review and meta-analysis of BRI in patients with NAFLD. In this study, extensive and rigorous methods were used to search published literature and perform meta-analysis. There are several limitations in this meta-analysis. First, there was significant and considerable heterogeneity among the included studies. This substantial heterogeneity could stem from variations in the participants' comorbid conditions and other characteristics, variations in study design, concomitant drug use, differences in NAFLD diagnostic methods, dietary habits, different adjusted covariates, and threshold values for the BRI. Second, due to the cross-sectional design of the included studies, it is not possible establish a cause-and-effect relationship between the BRI and NAFLD. Not all studies used the same method to diagnose NAFLD in participants, and none of them used liver biopsy, the gold standard for NAFLD diagnosis. Additionally, there is no consensus on the optimal cut-off values of BRI in the included studies. Lastly, the included studies had heterogeneous methods for reporting data; thus, pooling all included studies was not possible.

## Conclusion

In conclusion, BRI demonstrated a good diagnostic performance for NAFLD based on the findings of this study. These results highlight the possible utility of BRI as a non-invasive tool for assessing NAFLD. Subgroup analysis showed no statistically significant difference in diagnostic performance between female and male subgroups. While BRI appears to be a promising and cost-effective tool for NAFLD screening, the limited number of included studies and high heterogeneity among them warrant cautious interpretation of these findings. Further large-scale, high-quality studies are needed to validate the diagnostic accuracy of BRI and explore its clinical applicability. Incorporating BRI into routine practice may have the potential to improve early detection and management of NAFLD, but additional evidence is required to establish its role in clinical settings.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12944-025-02544-3.

Supplementary Material 1: Table S1: Search strategy. Table S2: Risk of bias assessment using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies. Table S3: GRADE methodology result. Supplementary Figure 1: Pooled mean differences in BRI between NAFLD and non-NAFLD groups by country. Supplementary Figure 2: BMI and mean differences meta-regression bubble plot. Supplementary Figure 3: The pooled area under the curve (AUC) for BRI in diagnosing NAFLD by country. Supplementary Figure 4: BMI and area under the curve (AUC) meta-regression bubble plot. Supplementary Figure 5: Publication bias assessment.

**Author contributions**
SK: supervision; methodology; writing-original draft; formal analysis; conceptualization; investigation; project administration. PF: writing-original draft; data preparation; investigation. AH: writing-original draft; data preparation; investigation. AET: writing-reviewing & editing; data curation. AAA: writing-reviewing & editing; data curation. PF: data preparation; writing-reviewing & editing. MSK: writing-reviewing & editing; supervision.

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**Data availability**
Data is provided within the manuscript or supplementary information files.

## Declarations

**Ethical approval**
Not Applicable.

**Competing interests**
The authors declare no competing interests.

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