

SYSTEMATIC REVIEW



Epidemiology and Population Health

Optimal BMI cut-offs associated with cardiometabolic risks in Arab and Middle Eastern populations: a systematic review and meta-analysis

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BACKGROUND: The global rise in obesity has prompted the need to explore population-specific Body Mass Index (BMI) thresholds. Current international guidelines may not reflect the cardiometabolic risks in Arab and Middle Eastern populations. This systematic review and meta-analysis aim to identify optimal BMI cut-offs associated with cardiometabolic morbidity and mortality in these populations.

METHODS: A systematic search of Medline and Embase databases identified observational and experimental studies focusing on BMI thresholds linked to cardiometabolic outcomes, including Diabetes Mellitus (DM), hypertension (HTN), dyslipidemia (DLP), cardiovascular diseases (CVD), and metabolic syndrome. Data extraction followed PRISMA guidelines, and random-effects models were used to calculate pooled estimates of optimal BMI cut-offs. Subgroup and sensitivity analyses were performed to address heterogeneity.

RESULTS: Fifty-five studies involving 677,587 participants met the inclusion criteria. Optimal BMI cut-offs ranged from 26.22 to 27.45 kg/m². For DM, the BMI threshold was 27.39 kg/m² (95% CI: 26.70–28.09), while HTN and MetS were associated with thresholds of 27.00 kg/m² and 27.45 kg/m², respectively. Gender differences were observed, with females showing higher BMI cut-offs than males. The sensitivity and specificity of these cut-offs were moderate, with high between-study heterogeneity ($I^2 > 90\%$). Publication bias was minimal for most outcomes, except DLP.

CONCLUSION: This study demonstrates that lower BMI thresholds are associated with cardiometabolic risks in Arab and Middle Eastern populations compared to global reports. Findings support the need for region-specific BMI cut-off guidelines and public health interventions targeting early diagnosis and management.

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INTRODUCTION

Obesity prevalence is increasing worldwide, including the middle east. The World Health Organization (WHO) has estimated the rate of obesity worldwide to be 890 million adults who were living with obesity [1]. The current prevalence of obesity in the middle east ranges between 32% (Yemen) and 43% (Qatar) [2]. However, the current definition of Obesity for Middle Eastern and Arab populations in epidemiological studies uses Body Mass Index (BMI), which was initially developed by Adolf Quetelet, a statistician in 1832 [3]. It was further used to define obesity based on a study by physiologist Ancel Keys in 1972 on a sample size of healthy men, the majority of whom were Caucasian men of European descent [4]. Women were not included in the study, and

the study did not represent different ethnicities, races, and backgrounds; specifically, no Arab or Middle Eastern individuals were included. In 1998, WHO used BMI (≥ 30) as a cut-off to reflect body adiposity and define obesity worldwide based on statistical data of the reference population [5]. However, in 2000, the WHO has redefined obesity for Asian-Pacific population using a lower BMI cut-off (≥ 25) based on associated mortality and morbidities with lower BMI [6]. BMI is a widely used tool in clinical practice to measure adiposity and for screening and management of obesity and its related comorbidities, despite its limitations. The limitations of BMI include indirect measurement of body fat, unable to assess the fat distribution, can underestimate obesity in sarcopenic individuals or overestimate fat in muscular individuals and

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does not distinguish between sex and other ethnic groups [7]. However, studies have shown a significant correlation between BMI and obesity-related complications. For example, a large population-based cohort study examining the association between BMI and the lifetime risk of cardiovascular disease has demonstrated that a higher BMI (≥ 30) is significantly associated with greater cardiovascular morbidity and mortality compared to normal BMI (< 25) [8]. Another study involving a large population of 18,061 participants examined the correlation between BMI, body fat percentage, and fat mass index using the gold standard method of dual-energy X-ray absorptiometry (DEXA) scan. The results showed that BMI is a strong predictor of body adiposity, with significant correlations to fat mass index ($r = 0.944$ in men and 0.976 in women) and percentage body fat ($r = 0.735$ in men and 0.799 in women) [9]. Despite the limitations of BMI, it continues to be used in the assessment of obesity, especially in epidemiological, population-based studies and in clinical practice, because of its simplicity and reproducibility.

The aim of this systematic review and meta-analysis is to identify the appropriate BMI cut-off associated with cardiometabolic risks for the Middle Eastern and Arab population.

MATERIALS AND METHODS

Protocol and registration

This systematic review and meta-analysis protocol was registered at the International Prospective Register of Systematic Reviews, PROSPERO 2024 (ID number: CRD42024538566). This study was performed as per PRISMA guideline (Preferred Reporting Items for Systematic Reviews and Meta-Analyses [10].

Eligibility criteria

Eligible studies included observational and experimental research on BMI cut-offs in Arab or Middle Eastern adults (> 18 years), examining associations with adverse clinical outcomes, such as hypertension (HTN), Diabetes Mellitus (DM), dyslipidemia (DLP), metabolic syndrome (MetS), cardiovascular disease (CVD), and morbidity. Fully published, peer-reviewed articles in English or Arabic were included as the main language of publication concerning the targeted demographical population, while reviews, case reports, animal studies, and non-original research were excluded. Abstract authors were contacted for full texts to ensure comprehensive data inclusion.

Data sources and search strategy

A comprehensive search was conducted by a librarian across Medline (1946 to 14 March 2024) and Embase (1947 to 14 March 2024) databases. The search strategy focused on three primary concepts: (1) Body mass index (BMI), including synonyms or related terms such as waist circumference, waist-to-hip ratio (WHR), waist-to-height ratio (WtHR) and obesity -AND- (2) Arab or Middle Eastern populations, defined by region, country, population, or ethnicity -AND- (3) optimal or specific BMI cut-off points (Supplementary Table A).

Both thesaurus terms (MeSH in Medline and Emtree in Embase) and text words (terms found in the Title, Abstract, or Author Keywords fields) were used to capture each concept comprehensively. To ensure all relevant human studies were captured, the Human indexing term was omitted due to the presence of both indexed and unindexed references in the databases.

Study selection and data extraction

Studies were organized and managed using the Covidence platform for systematic reviews (<https://www.covidence.org>). Titles and abstracts were screened independently by two reviewers (JN, AK, TH, SB), with any disagreements resolved by a third reviewer (JN, AK, AA). Full-text article screening was subsequently conducted by JN and AK, with conflicts resolved by AA or SB.

Inclusion criteria included fully published articles in peer-reviewed journals, encompassing observational and experimental studies, restricted to English and Arabic. Excluded were reviews, letters, case reports, commentaries, and animal studies. JM and AK contacted the authors of abstracts to obtain full articles as necessary.

Data extraction was carried out by JM and SB, capturing key study details, population characteristics, and BMI cut-off data linked to specific outcomes. Recorded information included title, publication year, first author, country, ethnicity classification, study design, and setting, along with objectives, study period, and duration. Baseline demographics (age, gender, BMI, and cardiovascular risk factors like smoking, DM, and HTN) were collected.

For BMI cut-offs related to outcomes, extracted data covered the Area Under the Curve (AUC), mean, standard deviation (SD), sensitivity, and specificity for DM, HbA1c, blood glucose, insulin resistance, blood pressure, DLP, cholesterol, LDL, HDL, triglycerides, MetS, CVD, and mortality.

Quality assessment

The quality of the included studies was assessed independently by JN and AK, and any disagreement was resolved by AA. As all included studies are observational studies, we used a modified version of the Newcastle-Ottawa scale (Supplementary Table B) combining factors for assessment of both cross-sectional and cohort studies [11–13]. The modified scale evaluates three main domains with a total of eight questions: selection bias (participant representativeness, sample size, missing data, and screening tool appropriateness), comparability bias (confounder assessment), and outcomes bias (e.g., outcome ascertainment, blinding, statistical tests, and follow-up adequacy). Questions are scored up to 1 star, except for the screening tool and outcome assessment, which allow up to 2 stars. Scores are classified as unsatisfactory (0–49%, high risk), satisfactory (50–69%, moderate risk), or good (70–100%, low risk) [11, 14, 15]. Additionally, the quality assessment results were presented using a traffic-light plot generated with the Robvis tool (RoB 2.0 cluster) for clear visualization. Each domain was categorized as unsatisfactory (high concern), satisfactory (moderate concern), or good (low/no concern) regarding risk of bias.

Data synthesis

The descriptive data were presented in mean and standard deviation. Youden's Index was calculated using the formula (Sensitivity + Specificity – 1) at each cut-off and meta-analysis was performed to determine the optimal BMI cut-off point associated with DM, HTN, DLP, CVD and MetS across all the studies. The random-effect model was used to identify the weighted mean difference (WMD) for the BMI cut-off and was illustrated using forest plots. The I^2 statistic was used to identify between-study heterogeneity with a threshold of significance at $p < 0.1$ (0–25%, 25.1–75%, and 75.1–100% representing a low, moderate, or high degree of heterogeneity, respectively) [16]. Furthermore, the regression-based Egger test for small-study effects was performed to identify publication bias with a threshold of significance at $p < 0.05$. At the same time, a funnel plot was used for illustration. To explain the causes of heterogeneity, the random-effect Meta-regression model was used to compare the subgroup differences and identify independent variables associated with the difference in BMI cut-off points.

In this study, we used metrics applied within a meta-analysis of diagnostic accuracy studies, pooling data from multiple sources to estimate overall test performance. A bivariate random-effects model was used to perform a meta-analysis of diagnostic test accuracy data, utilizing the metadta program. This model calculated pooled sensitivity, specificity, positive and negative likelihood ratios (LR+/LR–), and the diagnostic odds ratio (DOR), each with their respective 95% confidence intervals [17]. The

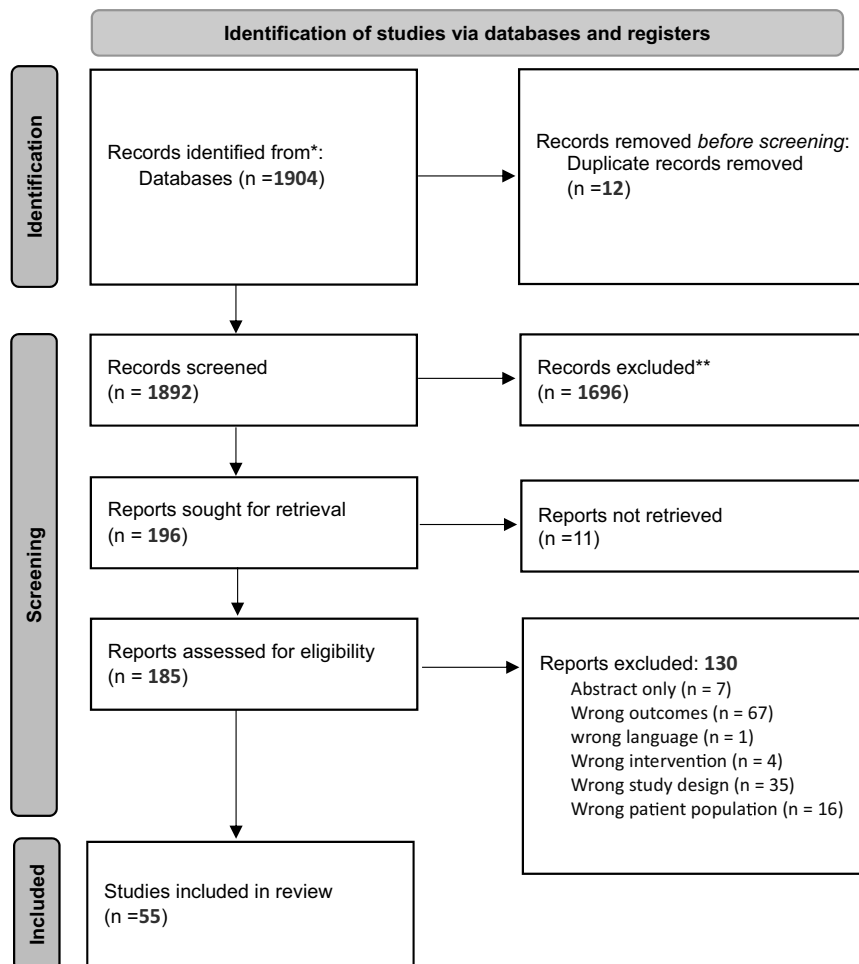


Fig. 1 Study Design. PRISMA flowchart of the study design.

Summary Receiver Operating Characteristic (SROC) curve estimated the area under the curve (AUC) and evaluated the diagnostic efficacy of BMI cut-off points associated with DM, HTN, DLP, CVD, and MetS. The model also accounted for between-study heterogeneity, incorporating the mean-variance relationship and the correlation between sensitivity and specificity.

The DOR expresses the overall effectiveness of a diagnostic test by combining sensitivity and specificity into a single metric, where a higher DOR indicates greater test accuracy. The LR+ and LR− quantify how much a test result increases or decreases the probability of disease presence. Additionally, the correlation coefficient between logit-transformed sensitivity and specificity reflects the inherent trade-off between these two parameters across studies, offering insights into their relationship.

STATA version 17.0 was used for statistical analysis (StataCorp, 1985–2021, Stata Statistical Software, College Station, TX, USA).

RESULTS

Study selection

We identified a total of 1904 studies through comprehensive searches of Medline and Embase databases. After removing 12 duplicates, 1892 unique studies were screened. During the screening process, 1696 studies were excluded for not meeting the predefined inclusion criteria. Consequently, we sought to retrieve 196 potentially relevant studies. Of these, 11 reports were not retrievable, leaving 185 studies for full-text eligibility assessment. Following the full-text review, 55 studies were

included in the systematic review and meta-analysis. The full study selection process is illustrated in Fig. 1 (PRISMA flow diagram).

Study characteristics

A total of 55 [18–72] studies met the inclusion criteria. The vast majority were cross-sectional in design, only a few were retrospective or prospective cohort, including 677,587 participants. Of these, 63% were female, and the mean age across the studies was 41.32 ± 0.69 years. The studies reported various clinical and demographic characteristics of participants, including BMI, fasting blood glucose (FBG), cholesterol levels, and CVD) risks. The mean BMI ranged from 23.14 to 34 kg/m², representing a diverse sample of normal, overweight, and individuals with obesity. Other key metrics, such as FBG, lipid profiles, and HTN prevalence, also varied across the studies. Many of the studies included participants with pre-existing conditions like DM, HTN, and DLP. The prevalence of these conditions ranged widely depending on the study population and region. Smoking status was reported in several studies, with rates varying from 0.2% to 40.3% (Supplementary Table C).

Quality assessment

All potential sources of bias as summarized into three main domains (selection bias, comparability/confounders bias and outcomes bias), were assessed. Of the 55 studies included [18–72], three studies [19, 21, 48] had a high risk of bias, 13 studies [20, 26, 28, 30, 38, 39, 41, 50, 58–60, 65, 68] had moderate risk of bias, and 39 studies [18, 22–25, 27, 29, 31–38, 40,

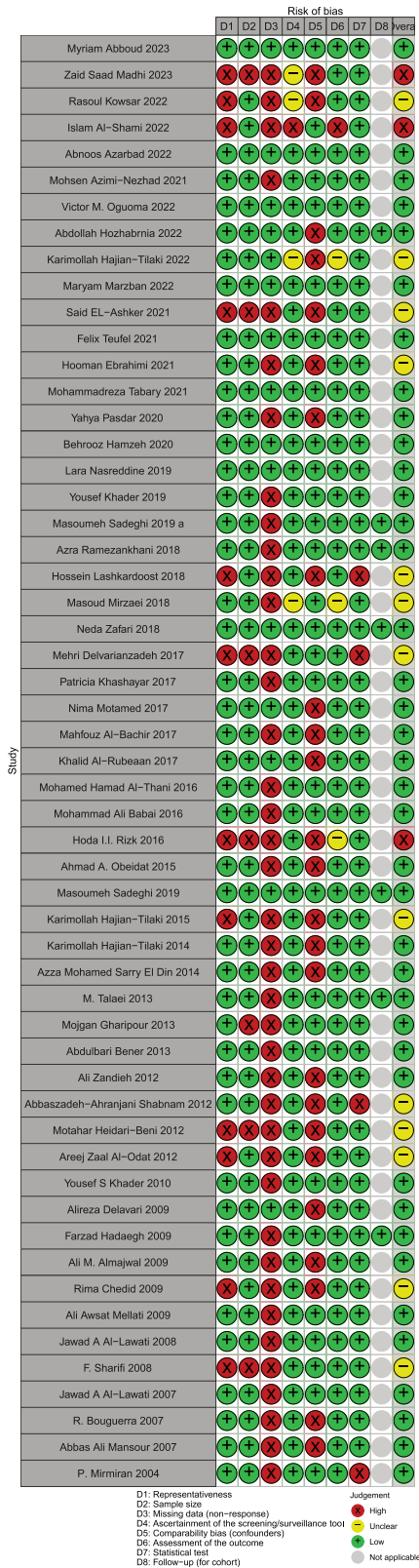


Fig. 2 Quality assessment. Quality assessment using Modified Newcastle-Ottawa scale for risk of bias for observational studies using Robvis tool for illustration.

42–47, 49, 51–57, 61–64, 66, 67, 69–72] had a low risk of bias. The overall risk-of-bias assessment is visually represented through the Robvis tool [73]. (Fig. 2).

BMI cutoffs and their associations with clinical outcomes

Diabetes mellitus (DM). As shown in Fig. 3A, a total of 19 studies were pooled in the meta-analysis examining BMI cutoffs associated with DM. The results demonstrated that the optimal BMI cutoff for DM diagnosis was 27.39 kg/m² (95% CI: 26.70–28.09). There was substantial between-study heterogeneity, as indicated by the high I² value of 98.95%, suggesting considerable variability across the included studies. A funnel plot (Supplementary Fig. A) showed no evidence of publication bias or small-study effects (p = 0.686).

In the subgroup analysis, a significant difference was observed in BMI cutoffs between males and females. Females had a higher BMI cutoff of 28.30 kg/m² (95% CI: 27.30–29.31) compared to 26.12 kg/m² (95% CI: 25.54–26.85) in males (p < 0.01). No significant differences were found when comparing age groups (<45 years vs. ≥45 years, p = 0.898) or between ethnic groups (Arab vs. non-Arab, p = 0.266) (Supplementary Table D).

The pooled sensitivity and specificity were 0.679 (95% CI: 0.630–0.724) and 0.630 (95% CI: 0.569–0.687), respectively. The DOR was 3.599, and the LR+ and the LR– were 1.835 and 0.509, respectively (Table 1).

The SROC curve provided an overall view of the trade-off between sensitivity and specificity, with the summary point located near 0.66 for sensitivity and 0.63 for specificity. The analysis revealed moderate diagnostic accuracy, with AUC of 0.655 (Fig. 4A). The correlation coefficient between logit-transformed sensitivity and specificity was not significant (0.055; 95% CI: –0.332 to 0.426).

Additionally, based on 7 studies, the meta-analysis examined the BMI cutoffs associated with impaired FBG. The pooled FBG-BMI cutoff was 26.00 kg/m² (95% CI: 25.11–26.88), with significant heterogeneity observed across studies (I² = 99.19%, p < 0.01). A funnel plot indicated slight asymmetry, suggesting potential small-study effects; however, this was not statistically significant (p = 0.068).

Hypertension (HTN). As shown in Fig. 3B, a total of 22 studies were pooled in the meta-analysis examining BMI cutoffs associated with HTN. The results demonstrated that the optimal BMI cutoff for HTN diagnosis was 27.00 kg/m² (95% CI: 26.30–27.69). There was substantial between-study heterogeneity, as indicated by the high I² value of 99.39%, suggesting considerable variability across the included studies. The funnel plot (Supplementary Fig. A) showed no significant evidence of publication bias, and the test for small-study effects was non-significant (p = 0.939).

In the subgroup analysis, a significant difference was observed between males and females. Females had a higher BMI cutoff of 28.16 kg/m² (95% CI: 27.30–29.02) compared to 26.22 kg/m² (95% CI: 25.36–27.07) in males (p < 0.01). No significant differences were found when comparing age groups (<45 years vs. ≥45 years, p = 0.254) or ethnic groups (Arab vs. non-Arab, p = 0.264) (Supplementary Table D).

The pooled sensitivity was 0.686 (95% CI: 0.636–0.732), and the pooled specificity was 0.586 (95% CI: 0.552–0.619). The DOR was 3.094, and the LR+ and the LR– were 1.657 and 0.536, respectively (Table 1).

The SROC curve provided an overall view of the trade-off between sensitivity and specificity, with the summary point located near 0.65 for sensitivity and 0.60 for specificity. The analysis revealed poor diagnostic accuracy, with AUC of 0.528 (Fig. 4B). The correlation coefficient between logit-transformed sensitivity and specificity was 0.447 (95% CI: 0.008 to 0.742).

Additionally, based on three studies, the meta-analysis examined BMI cutoffs associated with elevated systolic blood pressure (SBP). The pooled BMI cutoff was 26.09 kg/m² (95% CI: 24.85–27.33), with significant heterogeneity (I² = 97.10%,

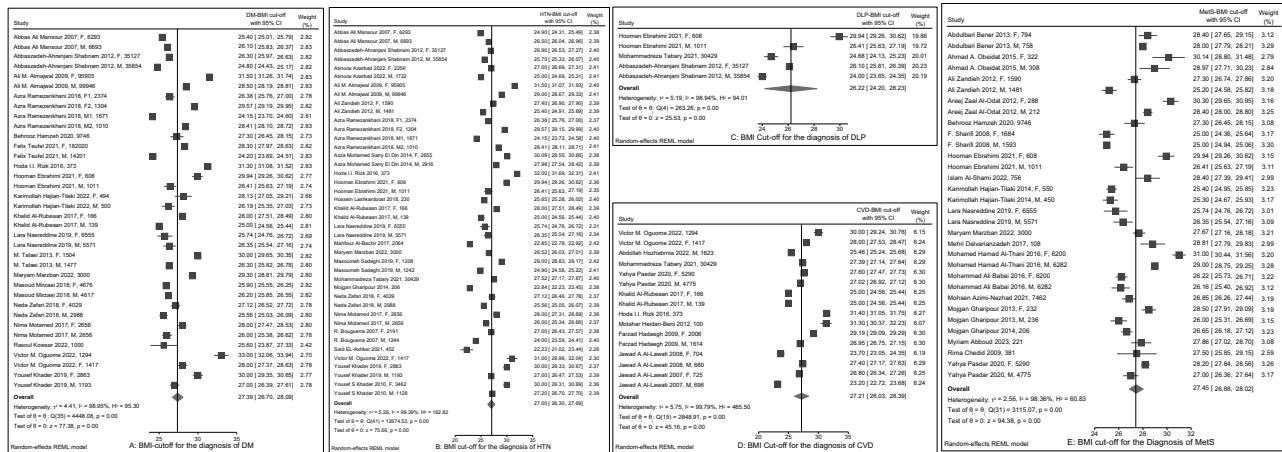


Fig. 3 Forest Plot. Forest plot of the BMI cut-off in the diagnosis of **A** DM, **B** HTN, **C** DLP, **D** CVD and **E** MetS, calculated using Youden's Index formula (Sensitivity + Specificity - 1).

$p = 0.00$). A funnel plot indicated slight asymmetry, but the test for publication bias was not statistically significant ($p = 0.207$).

Dyslipidemia (DLP). As shown in Fig. 3C, a total of three studies were pooled in the meta-analysis examining BMI cutoffs associated with DLP. The results demonstrated that the optimal BMI cutoff for DLP diagnosis was 26.22 kg/m^2 (95% CI: 24.20–28.23). There was substantial between-study heterogeneity, as indicated by the high I^2 value of 98.94%, suggesting considerable variability across the included studies. The funnel plot (Supplementary Fig. A) showed no significant evidence of publication bias or small-study effects ($p = 0.293$).

The SROC curve (Fig. 4C) provided an overall view of the BMI cutoffs for DLP, with the summary point estimated at approximately 0.62 for sensitivity and 0.61 for specificity. However, the pooled sensitivity and specificity could not be analyzed conclusively due to the small number of studies, and no further diagnostic accuracy data could be calculated.

In addition to the findings for DLP, based on four studies, the meta-analysis examined BMI cutoffs associated with elevated LDL cholesterol. The pooled BMI cutoff was 25.01 kg/m^2 (95% CI: 23.95–26.06), with significant heterogeneity ($I^2 = 98.15\%$, $p < 0.01$). A funnel indicated no evidence of publication bias ($p = 0.6336$).

Further expanding on the analysis, based on seven studies, the meta-analysis examined BMI cutoffs associated with elevated triglycerides (TG). The pooled BMI cutoff was 25.74 kg/m^2 (95% CI: 24.69–26.79), with a high degree of heterogeneity ($I^2 = 97.96\%$, $p < 0.01$). A funnel revealed no significant evidence of publication bias ($p = 0.4975$).

Finally, based on four studies, the meta-analysis examined BMI cutoffs associated with elevated total cholesterol levels. The pooled cholesterol-BMI cutoff was 25.27 kg/m^2 (95% CI: 24.06–26.49), with substantial heterogeneity across studies ($I^2 = 98.52\%$, $p < 0.01$) with a funnel plot showing slight asymmetry, and the test for publication bias was statistically significant ($p = 0.048$).

Cardiovascular diseases (CVD). As shown in Fig. 3D, a total of ten studies were pooled in the meta-analysis examining BMI cutoffs associated with CVD. The results demonstrated that the optimal BMI cutoff for CVD diagnosis was 27.21 kg/m^2 (95% CI: 26.03–28.39). There was substantial between-study heterogeneity, as indicated by the high I^2 value of 99.79%, suggesting considerable variability across the included studies. The funnel plot (Supplementary Fig. A) showed no significant evidence of publication bias, and the test for small-study effects was non-significant ($p = 0.597$).

In the subgroup analysis, no significant differences were found between age groups (<45 years vs. ≥ 45 years, $p = 0.993$) or ethnic groups (Arab vs. non-Arab, $p = 0.345$). Similarly, no significant differences were observed between males and females ($p = 0.280$) (Supplementary Table D).

The SROC curve (Fig. 4D) provided an overall view of the diagnostic performance of BMI cutoffs for CVD, with the summary point estimated at approximately 0.65 for sensitivity and 0.58 for specificity. However, the pooled sensitivity and specificity could not be analyzed conclusively due to the small number of studies, and no further diagnostic accuracy data could be calculated.

Metabolic syndrome (MetS). As shown in Fig. 3E, a total of 19 studies were pooled in the meta-analysis examining BMI cutoffs associated with MetS. The results demonstrated that the optimal BMI cutoff for MetS diagnosis was 27.45 kg/m^2 (95% CI: 26.88–28.02). There was substantial between-study heterogeneity, as indicated by the high I^2 value of 98.36%, suggesting considerable variability across the included studies. The funnel plot (Supplementary Fig. A) showed no significant evidence of publication bias, and the test for small-study effects was non-significant ($p = 0.263$).

In the subgroup analysis, a significant difference was observed between ethnic groups. Arab populations had a higher BMI cutoff of 28.53 kg/m^2 (95% CI: 27.66–29.41) compared to 26.82 kg/m^2 (95% CI: 26.22–27.43) for non-Arab populations ($p < 0.01$). No significant differences were found when comparing age groups (<45 years vs. ≥ 45 years, $p = 0.884$) or between males and females ($p = 0.093$) (Supplementary Table D).

The pooled sensitivity was 0.692 (95% CI: 0.647–0.734), and the pooled specificity was 0.651 (95% CI: 0.596–0.703). The DOR was 4.208, and the positive LR+ and LR- were 1.987 and 0.472, respectively (Table 1).

The SROC curve provided an overall view of the trade-off between sensitivity and specificity, with the summary point located near 0.68 for sensitivity and 0.62 for specificity. The analysis revealed poor diagnostic accuracy, with an AUC of 0.557 (Fig. 4E). The correlation coefficient between logit-transformed sensitivity and specificity was -0.224 (95% CI: -0.675 to 0.348).

DISCUSSION

In this study, we determined the BMI cutoffs values that were found to be associated with an increased cardiometabolic risks, including DM, HTN, DLP, CVD, and MetS among 677,587 Middle Eastern population. The thresholds, ranging from 26.22 to 27.45 kg/m^2 , suggest the need for adopting lower obesity cutoffs

Table 1. Meta-analysis of the diagnostic accuracy test of BMI cut-off in the diagnosis of clinical outcomes, A: DM, B: HTN, C: DLP, D: CVD and F: MetS.

Outcome	Number of articles included	Number of outputs from the included articles	BMI-cut-off by Youden's Index, [95% CI]	AUC	Summary sensitivity, [95% CI]	Summary specificity, [95% CI]	Diagnostic odds ratio (DOR)	Positive likelihood ratio (LR+)	Negative likelihood ratio (LR-)	Heterogeneity (between-study variability)	Correlation coefficient between the logit-transformed sensitivity and specificity, [95% CI]
A: DM	19	28	27.39 [26.70–28.09]	0.655	0.679 [0.630–0.724]	0.630 [0.569–0.687]	3.599	1.835	0.509	Variance for sensitivity: 0.302 vs. Variance for specificity: 0.460	0.055 [–0.332 to 0.426]
B: HTN	22	41	27.00 [26.30–27.69]	0.528	0.686 [0.636–0.732]	0.586 [0.552–0.619]	3.094	1.657	0.536	Variance for sensitivity: 0.243 vs. Variance for specificity: 0.093	0.447 [0.008–0.742]
C: DLP			26.22 [24.20–28.23]	Outputs cannot be analyzed due to the small number of articles							
D: CVD			27.21 [26.03–28.36]	Outputs cannot be analyzed due to the small number of articles							
F: MetS	19	32	27.45 [26.88–28.02]	0.557	0.692 [0.647–0.734]	0.651 [0.596–0.703]	4.208	1.987	0.472	Variance for sensitivity: 0.127 vs. Variance for specificity: 0.189	–0.224 [–0.675 to 0.348]

than those validated by the WHO for Western populations. The thresholds were identified based on the highest yielded AUROC values, yet these estimates were not high enough to achieve optimal accuracy. The analysis should be interpreted cautiously due to potential biases that may lead to either overestimation or underestimation of BMI cutoffs for association with cardiometabolic risks.

The study identified a BMI cutoff of approximately 27.39 kg/m² associated with DM, revealing notable gender differences. Females exhibited a higher BMI cutoff compared to males, with the diagnostic accuracy being moderate. Age and ethnicity did not significantly influence the cutoff, while impaired fasting blood glucose (FBG) was associated with a slightly lower BMI threshold of 26.00 kg/m². However, significant between-study variability was not explained by the subgroup-specific analyses.

The BMI cutoff derived from this analysis suggests that a lower threshold is needed for early screening of obesity and type II DM in Arab populations. The prevalence of DM in Arab populations was highest at 12.2% in 2019 and is expected to increase by 96% between 2019 and 2045 [74]. Notably, DM has a significant genetic predisposition, accounting for 24–69% of increased DM risk—greater than the contributions of BMI and body adiposity alone. This genetic factor was not accounted for in this study, particularly among ethnic groups with high prevalence, such as those in the Middle East [75].

The interpretation of this BMI cutoff and its association with DM risk must be approached cautiously, especially given the high heterogeneity and moderate diagnostic accuracy, which can impact clinical decision-making. These findings have implications for intervention strategies, including therapeutic targets for obesity and DM, bariatric surgery indications, and pharmacotherapy with weight-loss properties.

This study also emphasizes the importance of implementing Diabetes Prevention Programs (DPPs) in Arab and Middle Eastern populations for individuals with BMI levels lower than 27 kg/m². For comparison, DPPs in the United States recommend intervention for individuals with a BMI of 25 and above, or 23 and above for Asian Americans [76]. Public health policies tailored to the region can be developed based on these findings for early prevention obesity and DM.

The BMI cutoff associated with MetS risk was approximately 27.45 kg/m², with a significantly higher threshold for Arab populations compared to other subgroups. While the sensitivity and specificity were moderate, the overall diagnostic accuracy was poor. The diagnostic criteria for MetS used by the included studies are based on the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III), which includes waist circumference as a clinical measure of central obesity instead of BMI. However, the cut-off used by NCEP is also based on populations of white ethnicity and/or Asian population with no specific cut-off for Arab population. This analysis did not investigate a waist circumference cut-off specific to our ethnic group, which may underestimate MetS in the Middle Eastern population.

In our study, the risk of HTN was substantially linked to pooled BMI of 27.00 kg/m²; however, the estimate might be affected due to substantial heterogeneity in involved studies. Data from the Chinese Health and Nutrition Survey (2000–2004) showed that the 4-year incidence of HTN was 13% in women and 19% in men, which was found to have a positive association with higher BMI levels. BMI cutoffs of 22.5 kg/m² and 23.5 kg/m² were highly linked to HTN in men and women, respectively [77]. These measures yielded the highest sensitivity and specificity for predicting HTN risk, which was 60% for both. The area under receiver operating characteristic curve (AUROC) of these thresholds were 0.62 (95% CI: 0.59–0.65) for men and 0.62 (95% CI: 0.58–0.65) for women, with age-adjusted AUCs rising to 0.68 (95% CI: 0.65–0.70) for men and 0.71 (95% CI: 0.68–0.74) for

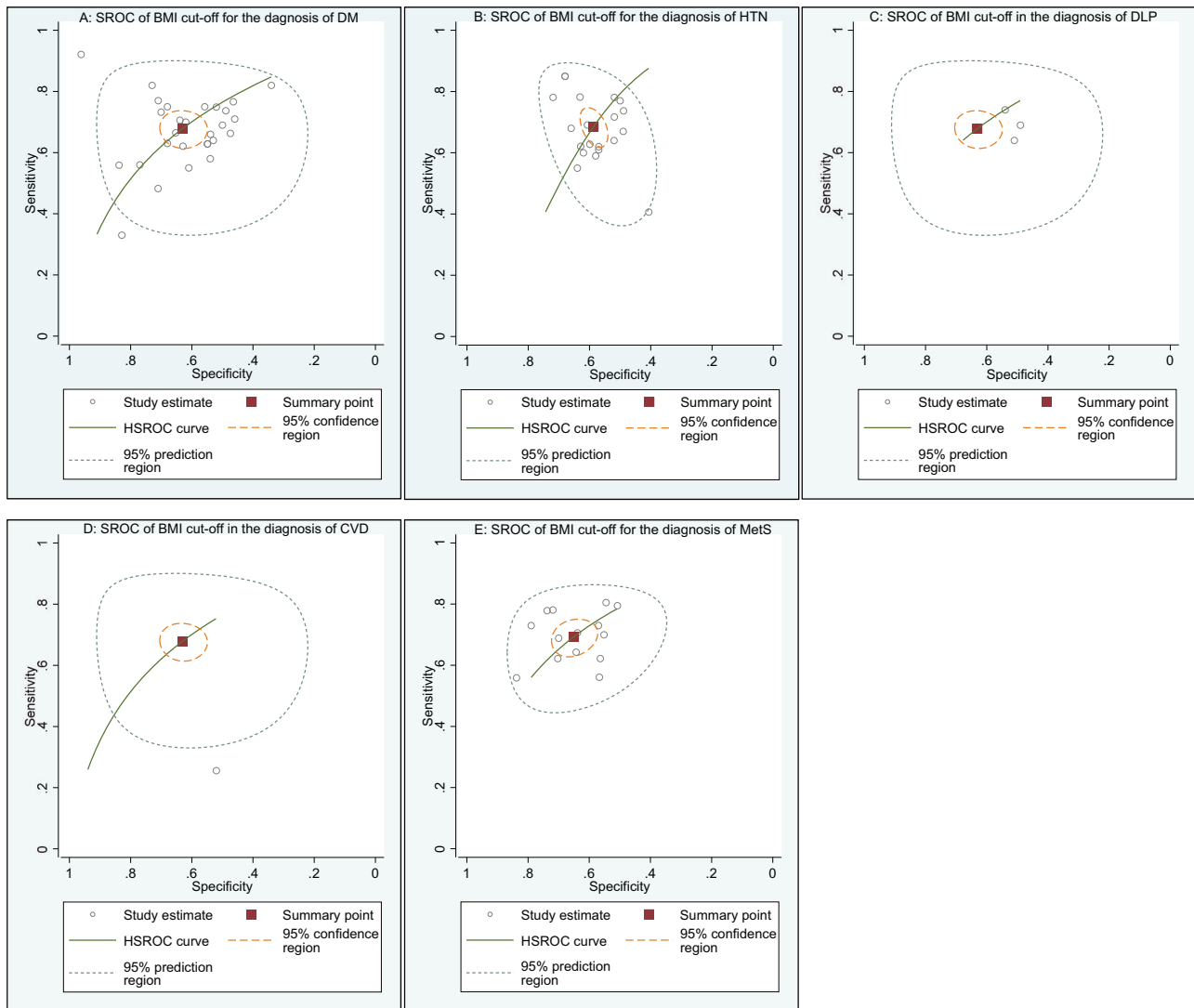


Fig. 4 Receiver operating characteristics curves. Summary of receiver operating characteristics curve (SROC) of BMI cut-off in the diagnosis of **A** DM, **B** HTN, **C** DLP, **D** CVD and **E** MetS.

women [77]. Another Indian study showed a higher cutoff for BMI that predicted HTN among the North Indian population, which was 22.8 kg/m² in men and 28.8 kg/m² in women [78]. The results from these studies and our findings suggest adopting lower BMI thresholds for overweight status to capture HTN risk in Asian populations, diverging from the higher Western standards. The risk for HTN was related to a BMI cutoff of 28.16 kg/m² for Middle Eastern females, which was like Indian female threshold. For Middle Eastern males, a higher BMI cutoff of 26.22 kg/m² was determined compared to Asian males.

Higher risk of DLP was determined at a BMI cutoff of 22–23 kg/m² for men and 24–25 kg/m² for women in the Taiwanese population [79]. In a Chinese study, a BMI of 24 kg/m² had the best sensitivity and specificity for identification of cardiovascular disease risk factors, including DLP, hence it was identified as the cutoff point for overweight. It also showed that a BMI of 28 kg/m² had a specificity of approximately 90% and was determined as the cutoff point for obesity [80]. Our study found a BMI of 26.2 kg/m² to be optimal for identifying the risk of DLP, which is lower than the Chinese threshold. However, the diagnostic accuracy of the BMI cutoff for DLP was modest, with sensitivity and specificity values clustering around 62% and 61%, respectively. These results were extracted from a limited number of studies, which restrain

comprehensive analysis, highlighting the need for more data to strengthen these estimates.

Despite inconsistent findings regarding the discriminatory performance of BMI in predicting CVD events and mortality [81, 82], several studies concluded that older adults with BMI above 25 kg/m² had a lower risk of all-cause mortality compared to those in the normal-weight range [83, 84]. In fact, the risk for both total and CVD mortality was estimated to be lower by 13% (95% CI: 6%–19%) and 12% (2%–25%), respectively, compared to their normal counterpart [85].

Cumulatively, there was a high degree of heterogeneity observed across the included studies, which is a recognized limitation in meta-analyses of diagnostic thresholds [86]. To address this, we conducted multiple subgroup analyses and meta-regressions. Gender-based subgroup analysis revealed significantly higher BMI cut-offs in females compared to males for both DM and HTN, which partially explained between-study variability. Similarly, a significant difference was found between Arab and non-Arab populations in BMI cut-offs associated with MetS. However, no significant differences were observed across age groups or for CVD, suggesting that residual heterogeneity may be due to methodological differences, outcome definitions, or unmeasured population characteristics [87]. The use of a bivariate

random-effects model further accounted for between-study variance and incorporated sensitivity-specificity correlations [88]. These findings highlight the complexity of BMI as a diagnostic proxy across diverse populations and support the need for tailored cut-offs while acknowledging the inherent variability in epidemiologic data synthesis.

This study has several strengths, including a large sample size and comprehensive data derived from 55 studies, which enhance the robustness and reliability of the findings. By focusing on Arab and Middle Eastern populations, the research addresses a significant gap in the literature, providing valuable insights into a previously underrepresented group. Moreover, the study offers actionable BMI thresholds that can guide region-specific public health policies and clinical guidelines. These thresholds provide a practical foundation for early screening and intervention strategies, especially in settings where advanced diagnostic tools may not be readily available, contributing to improved cardiometabolic risk assessment and management in these populations.

However, there are limitations that warrant consideration. BMI, while widely used, has inherent shortcomings as a diagnostic tool, including its inability to differentiate between fat and lean mass or assess fat distribution. Future studies should explore the relationship between BMI and body composition using advanced methods such as dual-energy X-ray absorptiometry (DEXA) or bioelectrical impedance analysis to refine the understanding of obesity-related health risks.

These approaches could address BMI's diagnostic limitations while improving the precision of cardiometabolic risk assessments.

Additionally, high heterogeneity across the included studies poses challenges to generalizing the findings to all subpopulations within the region. The reliance on retrospective studies further limits the ability to establish causal relationships between BMI cutoffs and cardiometabolic outcomes. Moreover, the lack of prospective studies and detailed subgroup analyses on ethnic variations within Arab and Middle Eastern populations constrains the applicability of the results. Addressing these limitations through future research will strengthen the evidence base and improve the relevance of BMI cutoffs across diverse demographic and clinical contexts. However, because of the limitations of using anthropometric measures to define obesity, a broader and more holistic definition of obesity has been suggested by experts in the field. For example, a commission has published a new definition for Obesity and Clinical Obesity that moves away from using of any anthropometric measures, including BMI. The commission defines obesity as a condition characterized by excess adiposity, in the presence or absence of abnormal distribution or function of the adipose tissue, and Obesity causes are multifactorial and still not fully understood [89]. The commission also has defined clinical obesity as a chronic disease with excess adiposity that leads to alteration of the functions of body organs and leading to multiple end-organ damage and various health risk, such as the ones we have explored in our study [89]. To define obesity, we should not rely only on anthropometric measures but also the clinical implications of obesity.

CONCLUSION

This systematic review and meta-analysis emphasize the need for lower BMI cut-offs to better assess cardiometabolic risks in Arab and Middle Eastern populations. The identified thresholds, ranging from 26.22 to 27.45 kg/m², highlight significant deviations from global reports, reflecting unique genetic, cultural, and environmental influences in these populations. Adopting these region-specific BMI cut-offs associated with cardiometabolic risks can enhance early detection and management. The results also provide a foundation to inform region-specific public health policies and clinical guidelines.

DATA AVAILABILITY

All necessary data are included; further data are not available for sharing.

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AUTHOR CONTRIBUTIONS

Conceptualization: AK, TH, and AA, Data curation: AK, TH, SB, JN, JM, and AA, Methodology: AK, TH, SB, JN, JM, and AA, Investigation: AK, TH, SB, and JN, Resources: AK, Software: AK, Formal analysis: JM and SB, Funding acquisition: AK, Project administration: AK, Supervision: AK and AA, Validation: SB and JM, Visualization: SB and JM, Roles/Writing—original draft: all authors, Writing—review & editing: all authors.

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COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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