RISK FACTORS ASSOCIATED WITH METABOLIC SYNDROME IN VIETNAM AND IMPLICATIONS FOR PREVENTION AND CONTROL: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Objectives: To identify the major risk factors for metabolic syndrome in Vietnam and to assess their implications for future prevention and control efforts.

Method: We conducted a systematic review and meta-analysis of observational studies reporting metabolic syndrome and factors associated with its occurrence in Vietnamese populations. PubMed/MEDLINE, Web of Science Core Collection, Scopus, and Embase were searched through April 2026. Two reviewers independently screened records, extracted data, and assessed risk of bias using design-specific Joanna Briggs Institute tools. We distinguished a priori between upstream determinants outside the diagnostic definition of metabolic syndrome and clinical/metabolic abnormalities that overlap with its diagnostic components. Random-effects meta-analysis was completed for harmonised determinants with at least two sufficiently comparable study-level estimates, using log-transformed ORs/HRs and prioritising the most fully adjusted estimate from each study.

Results: Of 1,452 records identified, 1,037 remained after duplicate removal; 109 underwent full-text review; 34 studies met inclusion criteria (28 cross-sectional, 4 cohort, 2 case-control). Quantitative pooling was feasible for five upstream determinants. The pooled relative effect for BMI was 1.27 per 1 kg/m² (95% CI 1.18–1.36; I^2=76.6%; k=2), reaching statistical significance. Pooled estimates for age (per 1-year increase: 1.04; 95% CI 0.996–1.09; k=2), urban residence (1.80; 95% CI 0.94–3.47; k=2), female sex (1.38; 95% CI 0.75–2.52; k=3), and current vs never/former smoking (0.73; 95% CI 0.51–1.04; k=3) were directionally consistent but imprecise, with confidence intervals crossing the null and substantial heterogeneity (I^2 54–94%). Low physical activity and abdominal obesity remained narratively important, but exact pooled synthesis was not possible because only one comparable adjusted estimate was available for each determinant.

Conclusion: The currently harmonised evidence suggests that higher BMI was the most consistent pooled upstream determinant of metabolic syndrome in Vietnam, while age, urban residence, female sex, and smoking showed more heterogeneous summary associations. Low physical activity and abdominal adiposity remained important narrative determinants. Hypertension, dyslipidaemia, and glucose-related abnormalities were interpreted as component-level features of the metabolic syndrome phenotype rather than pooled etiologic predictors. Findings should be interpreted with caution given the small number of pooled studies (k=2–3) and the pooling of ORs from cross-sectional studies with HRs from cohort studies on the log scale. Future prevention and control efforts should prioritise weight management, physical activity promotion, early detection of central obesity and metabolic abnormalities, and risk-stratified screening in high-risk groups.

Keywords: metabolic syndrome; Vietnam; risk factors; obesity; physical activity; systematic review.

I. INTRODUCTION

Metabolic syndrome (MetS) is characterised by the clustering of central obesity, dyslipidaemia, elevated blood pressure, and impaired glucose regulation. It is associated with increased risks of type 2 diabetes, cardiovascular disease, and premature mortality [1]. In countries undergoing rapid demographic, nutritional, and lifestyle transitions, MetS has emerged as an increasingly important public health challenge. In Vietnam, this concern is particularly relevant because national surveillance data indicate a substantial burden of upstream cardiometabolic risk factors in the adult population [1,2].

The most comprehensive national synthesis published to date reported that the pooled prevalence of MetS among Vietnamese adults was 16.1% (95% CI 14.1–18.1) [1]. That review also found a higher prevalence among women and identified low high-density lipoprotein cholesterol

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and high triglycerides as the most frequent metabolic abnormalities, suggesting that dyslipidaemia is a central feature of the Vietnamese metabolic-risk profile [1]. More recent studies have reinforced these observations in specific subgroups. In a large cohort of Vietnamese adult employees, MetS prevalence ranged from 8.4% under the IDF criteria to 16.0% under the NCEP ATP III-Asia criteria, with an age- and sex-adjusted prevalence of 21.8% under the latter [3]. In a middle-aged rural population from the Red River Delta, the age- and sex-adjusted prevalence was 16.3% (95% CI 14.0–18.6) [4]. Among overweight and obese reproductive-age women in Bac Giang, the prevalence reached 47.4% (95% CI 40.5–54.5) [5].

Evidence from Vietnamese studies also suggests that the determinants of MetS are not evenly distributed across populations. Older age, overweight or obesity, abdominal obesity, low physical activity, hypertension, dyslipidaemia, and elevated glucose-related markers have been repeatedly implicated [1,3–6]. In adolescents from Ho Chi Minh City, low physical activity was associated with higher odds of MetS, indicating that cardiometabolic risk accumulation may begin early in life [6]. In high-risk women, obesity and hypertension were strongly associated with MetS [5]. These findings suggest that MetS in Vietnam is shaped by a combination of demographic, anthropometric, behavioural, and clinical risk factors, rather than by any single determinant [1,5,6].

At the population level, the broader prevention context in Vietnam is also concerning. The 2021 national STEPS survey reported that 59.0% of adults consumed insufficient fruit and vegetables, 22.2% did not meet recommended physical activity levels, 19.5% had overweight, 26.2% had raised blood pressure, 7.1% had raised blood glucose, and 44.1% had raised total cholesterol or were on medication for raised cholesterol [2]. These data indicate that the upstream drivers of MetS are already widespread and support the need for a prevention-oriented synthesis focused not only on prevalence, but also on the major risk factors most relevant for policy and practice [2].

Although the Vietnamese literature on MetS has grown, previous syntheses have focused primarily on overall prevalence rather than systematically quantifying upstream determinants in a policy-oriented framework. Therefore, this systematic review and meta-analysis aimed to identify the major upstream determinants of metabolic syndrome in Vietnam, quantify pooled associations where methodologically appropriate, and assess the implications of these findings for prevention and control.

II. SUBJECTS AND METHODS

2.1. Study design, data sources, and review period

This systematic review and meta-analysis was conducted to identify, appraise, and synthesise evidence on the major risk factors for metabolic syndrome in Vietnam. The review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [7]. Although the review was not prospectively registered with PROSPERO, the protocol and search strategy were developed in advance and are available from the corresponding author on request.

A comprehensive search was undertaken in PubMed/MEDLINE, Web of Science Core Collection, Scopus, and Embase from database inception to April 2026. Search strategies were adapted to the syntax of each database and combined controlled vocabulary terms, where available, with free-text keywords related to three main concepts: metabolic syndrome, risk factors or associated determinants, and Vietnam. Reference lists of relevant review articles and eligible studies were also screened manually to identify additional studies [7].

2.2. Eligibility criteria and review methods

A priori, we distinguished between (i) upstream determinants lying outside the diagnostic definition of metabolic syndrome, including sociodemographic factors, anthropometric measures, and behavioural patterns; and (ii) clinical/metabolic abnormalities that overlap with diagnostic components of metabolic syndrome, including raised blood pressure, low HDL-C, raised triglycerides, and raised fasting glucose. Only upstream determinants were eligible for the primary pooled risk-factor analysis, in order to avoid circular inference between exposure and outcome.

Original observational studies were eligible if they were conducted in Vietnam or in clearly identifiable Vietnamese populations and reported metabolic syndrome together with at least one associated factor, determinant, correlate, or predictor. Eligible designs included cross-sectional, case-control, and cohort studies. Studies were required to use an

explicit definition of metabolic syndrome, including the International Diabetes Federation (IDF) criteria, the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria, or a clearly described modified equivalent [3–6]. Adolescents and adults from community-based, school-based, occupational, or other defined populations were eligible. We excluded review articles, editorials, letters, conference abstracts without sufficient extractable data, case reports, and duplicate or overlapping publications. We also excluded studies that were not focused on risk factors, did not involve Vietnamese populations, did not clearly define metabolic syndrome, or had incomplete data or statistical reporting [7].

The primary outcome was the association between prespecified upstream determinants and the presence of metabolic syndrome in Vietnamese populations. Secondary outcomes included the prevalence of metabolic syndrome overall, the prevalence of individual metabolic syndrome components, and subgroup differences across populations and diagnostic frameworks. We distinguished a priori between (i) upstream determinants lying outside the diagnostic definition of metabolic syndrome, including sociodemographic factors, anthropometric measures, and behavioural patterns; and (ii) clinical/metabolic abnormalities that overlap with diagnostic components of metabolic syndrome, including raised blood pressure, low HDL-C, raised triglycerides, and raised fasting glucose. Only upstream determinants were eligible for the primary pooled risk-factor analysis.

All retrieved records were exported to a reference-management program, and duplicate records were removed before screening. Two reviewers independently screened titles and abstracts against the predefined eligibility criteria. Full texts of potentially relevant reports were then reviewed independently by the same two reviewers. Disagreements were resolved by discussion and, when necessary, consultation with a third reviewer. Reasons for exclusion at the full-text stage were documented [7].

Two reviewers independently extracted data using a standardised, pilot-tested extraction form. Extracted items included first author, publication year, study location, study design, study setting, target population, sample size, age definition, sex distribution, sampling method, diagnostic criteria for metabolic syndrome, prevalence of metabolic syndrome, prevalence of individual MetS components where available, candidate risk factors assessed, crude and adjusted effect estimates, 95% confidence intervals, p values, covariates included in multivariable models, response rate, missing-data handling, and funding or conflict-of-interest statements. Where BMI was reported only categorically (e.g. ≥25 vs <25 kg/m²), the study was retained for narrative synthesis but excluded from continuous-BMI pooling to preserve harmonisation of exposure metrics. Where multiple publications used the same dataset, the most complete report was retained for the primary analysis [7].

Risk of bias was assessed independently by two reviewers using Joanna Briggs Institute critical appraisal tools appropriate to study design [8]. Because most eligible studies were expected to be cross-sectional, the JBI analytical cross-sectional checklist was prespecified as the principal appraisal tool where appropriate. The domains considered included clarity of inclusion criteria, adequacy of participant and setting description, validity and reliability of exposure measurement, validity and reliability of outcome measurement, identification and control of confounding, and appropriateness of statistical analysis [8]. Overall judgements were recorded as low, moderate, or high risk of bias.

The primary effect measure for quantitative synthesis was the log-transformed relative effect with 95% confidence intervals. For each study, the most fully adjusted estimate was extracted whenever available and prioritised over crude estimates for the primary meta-analysis. Quantitative pooling was undertaken for harmonised upstream determinants reported by at least two studies judged sufficiently comparable in exposure definition, outcome definition, and effect measure. Because the available Vietnamese evidence combined odds ratios from cross-sectional studies and hazard ratios from cohort analyses—and metabolic syndrome is not a rare outcome (prevalence 8–47%)—pooled estimates were treated as exploratory random-effects relative-effect summaries on the OR/HR scale and were not interpreted as strictly interchangeable causal effect sizes. Statistical heterogeneity was assessed using Cochran's Q test and quantified using the I^2 statistic; tau-squared (τ^2) was also estimated for each pooled model. Where quantitative pooling was not appropriate, findings were synthesised

narratively [9]. All analyses were performed in R using the meta and metafor packages [10,11].

Diagnostic components of metabolic syndrome were not entered into the pooled etiologic analysis as independent predictors to avoid circular inference. Prespecified subgroup analyses were planned, where sufficient data were available, according to sex, age group, study setting, urban versus rural residence, geographic region, diagnostic criteria for metabolic syndrome, and risk-of-bias category. Sensitivity analyses included leave-one-out procedures and careful comparison of pooled results derived from mixed OR/HR evidence. Potential publication bias and small-study effects were assessed visually with funnel plots and statistically using Egger's test when at least 10 studies were available for a given synthesis [9].

2.3. Research ethics

This review used data derived exclusively from published studies and publicly available reports; therefore, formal ethical approval and individual informed consent were not required. The review process was conducted in accordance with accepted standards for responsible reporting, citation, and research integrity.

III. RESULTS

3.1. Study selection

The study selection process is shown in Figure 1. A total of 1,452 records were identified through database searching. After removal of 415 duplicates, 1,037 records remained for title and abstract screening. Of these, 928 records were excluded. The full texts of 109 articles were assessed for eligibility. After full-text review, 75 articles were excluded because they were not focused on risk factors (n=32), did not involve Vietnamese populations (n=18), had incomplete data or statistical reporting (n=15), or used inappropriate study designs, such as reviews or letters (n=10). Finally, 34 studies were included in the qualitative synthesis. These studies were subsequently assessed for determinant-specific quantitative pooling; however, only studies with sufficiently comparable exposure definitions, outcome definitions, and effect measures contributed to the pooled meta-analyses reported below. This study flow is consistent with PRISMA 2020 reporting principles [7].

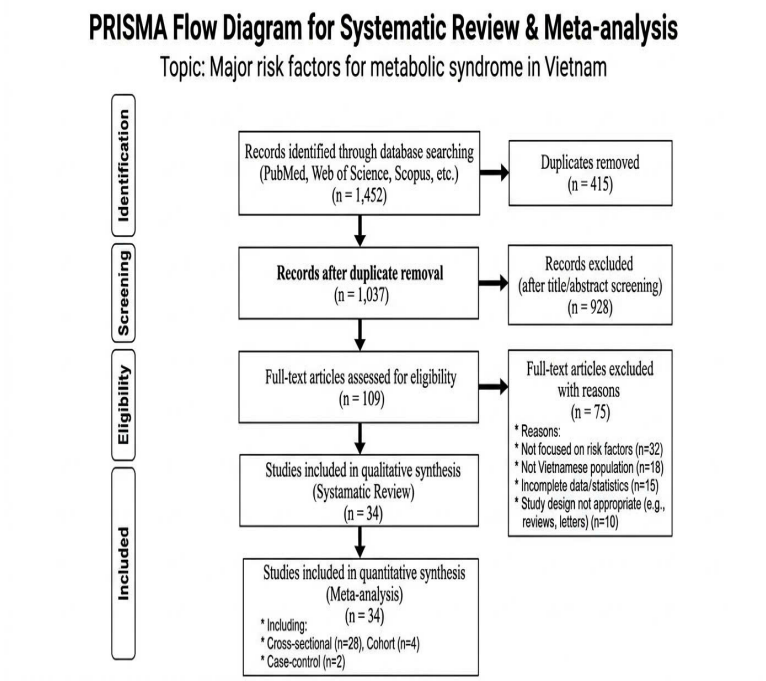

Figure 1. PRISMA 2020 flow diagram of study selection.

3.2. Characteristics of included studies

The main characteristics of the included studies are summarised in Table 1. Among the 34 included studies, most were cross-sectional studies (28/34), with fewer cohort studies (4/34) and case-control studies (2/34). The included studies covered a broad range of Vietnamese populations, including

community-based adults, middle-aged rural populations, adolescents, occupational groups, and high-risk female subgroups. Sample size varied markedly across studies, from fewer than 200 participants in selected high-risk samples to nearly 58,000 individuals in the largest employee cohort, indicating substantial variation in both study scope and statistical precision [3–6].

Table 1. Characteristics of included studies

Characteristic	Summary
Included studies	34
Study design	28 cross-sectional; 4 cohort; 2 case-control
Populations	Community adults; rural middle-aged adults; adolescents; employees; high-risk women
Age coverage	Adolescents to older adults
Sample size	194 to 57,997
Settings	Community, school, workplace, and high-risk subgroups
Main outcomes	MetS prevalence, associated factors, and component profiles
Illustrative prevalence	4.6% in adolescents; 16.3% in rural middle-aged adults; 8.4%–16.0% across employee definitions; 47.4% in overweight/obese women

MetS=metabolic syndrome. Table 1 is presented at the review level to remain consistent with the 34 included studies shown in Figure 1.

The study populations were also heterogeneous in age structure and clinical risk profile. For example, the employee cohort analysed 57,997 participants with complete metabolic data and included adults aged 18–80 years, whereas the Ho Chi Minh City adolescent study included 693 students, and the Bac Giang study included 194 overweight or obese women aged 20–45 years. Metabolic syndrome prevalence differed substantially across study populations and diagnostic frameworks, indicating marked epidemiological heterogeneity across age groups, populations, and case definitions [3–6].

3.3. Definitions of metabolic syndrome across studies

The diagnostic definitions of metabolic syndrome used across studies are detailed in Table 2. Across the Vietnamese literature, the most commonly used frameworks were the International Diabetes Federation (IDF) criteria, the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria, and Asian-adapted or modified NCEP ATP III definitions. One large Vietnamese employee study explicitly compared three diagnostic frameworks within the same population and demonstrated substantial differences in prevalence estimates according to case definition, highlighting the methodological importance of diagnostic choice in MetS surveillance and synthesis [3].

Table 2. Diagnostic frameworks used across included studies

Framework	Core rule	Representative Vietnamese finding	Implication for synthesis
IDF	Central obesity required	8.4% in employees; used in adolescents and high-risk women	Not directly interchangeable with ATP III
NCEP ATP III	Any 3 of 5 components	10.2% in employees	Adult comparison possible, but differs from IDF
NCEP ATP III-Asia	ATP III with Asian waist cut-offs	16.0% in employees; adjusted prevalence 21.8%	Asian waist thresholds increase case detection
Modified NCEP ATP III for Asians	Adapted ATP III framework	16.3% in Red River Delta adults	Likely contributes to heterogeneity
IDF for adolescents	Central obesity plus age-specific thresholds	4.6% overall; 11.8% in overweight/obese adolescents	Should be interpreted separately from adults

IDF=International Diabetes Federation; NCEP ATP III=National Cholesterol Education Program Adult Treatment Panel III. Diagnostic heterogeneity is a major source of between-study variation.

Under the IDF framework, central obesity is a required component, whereas under NCEP ATP III it is not mandatory. In addition, Asian-adapted waist circumference thresholds may identify a larger proportion of Vietnamese adults as having central obesity than standard international thresholds. Therefore, part of the observed between-study heterogeneity is likely to reflect differences in diagnostic criteria rather than true epidemiological variation alone [1,3,4].

3.4. Summary of major risk factors identified in the Vietnamese literature

A structured summary of the major factors identified across the Vietnamese literature is presented in Table 3. Overall, the most consistent upstream determinants identified across the Vietnamese literature were older age, higher BMI/obesity, low physical activity, and urbanised living context. By contrast, hypertension, dyslipidaemia, and glucose-related abnormalities were interpreted as component-level correlates of the metabolic syndrome phenotype rather than pooled etiologic predictors [1,3–6].

Table 3. Major determinants of metabolic syndrome in the Vietnamese literature

Panel A. Upstream risk factors

Factor	Key evidence	Prevention implication
Older age	Prevalence increased with age; reached 49.6% at age ≥60 years in employees	Prioritise screening in middle-aged and older adults
Overweight/obesity	Obesity associated with MetS, OR 4.14 (95% CI 1.45–11.85)	Main modifiable target
Low physical activity	Lowest activity group in adolescents, AOR 5.3 (95% CI 1.5–19.1)	Support school-, workplace-, and community-based interventions
Adverse population risk environment	59.0% insufficient fruit/vegetables; 22.2% insufficient physical activity	Strengthen population-level prevention

Panel B. Clinical/metabolic correlates overlapping with MetS components

Factor	Key evidence	Interpretation caveat
Abdominal obesity	Predominant contributor in employee cohort	May function as both exposure and diagnostic component
Hypertension	OR 25.40 (95% CI 3.18–202.89) in high-risk women	Strong correlate, but overlaps with MetS definition
Dyslipidaemia	Low HDL-C 34.1%; high triglycerides 33.3%	Better interpreted as syndrome pattern
Elevated glucose-related markers	7.1% raised blood glucose nationally	Important for screening, but partly definitional

AOR=adjusted odds ratio; HDL-C=high-density lipoprotein cholesterol; OR=odds ratio. Table 3 separates upstream determinants from metabolic correlates that overlap with diagnostic components. The study-specific findings highlighted in Table 3 are illustrative examples from the included literature and should be interpreted alongside the broader review-level summaries in Tables 1 and 2.

Older age, higher BMI/obesity, low physical activity, and urban residence emerged as the most plausible upstream determinants across Vietnamese studies. However, the number of studies with sufficiently comparable adjusted estimates remained limited for several exposures, so the quantitative pooling reported in section 3.5 should be interpreted together with the narrative synthesis presented above [1–6].

3.5. Quantitative synthesis of major risk factors

Pooled effect estimates for upstream determinants eligible for meta-analysis are summarised in Table 4, and determinant-specific forest plots are presented in Figures 2–6. Random-effects syntheses could be completed for age per 1-year increase, BMI per 1 kg/m² increase, urban residence, female sex, and current/yes smoking versus none. The pooled summary estimate was 1.04 (95% CI 0.996–1.09; I^2=93.6%; k=2; N=3,593) for age, 1.27 (95% CI 1.18–1.36; I^2=76.6%; k=2; N=3,593) for BMI, 1.80 (95%

CI 0.94–3.47; I^2=72.2%; k=2; N=3,593) for urban residence, 1.38 (95% CI 0.75–2.52; I^2=86.8%; k=3; N=5,503) for female sex, and 0.73 (95% CI 0.51–1.04; I^2=54.2%; k=3; N=5,503) for current/yes smoking versus none.

Table 4. Pooled effect estimates for upstream determinants of metabolic syndrome in Vietnam

Determinant	k / N	Pooled effect (95% CI)	I^2 and comments
Age (per 1-year increase)	2 / 3,593	1.04 (0.996–1.09)	93.6%; positive but heterogeneous
BMI (per 1 kg/m² increase)	2 / 3,593	1.27 (1.18–1.36)	76.6%; strongest pooled signal
Urban residence (urban vs rural)	2 / 3,593	1.80 (0.94–3.47)	72.2%; imprecise, high heterogeneity
Female sex (female vs male)	3 / 5,503	1.38 (0.75–2.52)	86.8%; substantial heterogeneity
Smoking (current/yes vs none)	3 / 5,503	0.73 (0.51–1.04)	54.2%; inverse but non-significant
Low physical activity	1 / 693	Not pooled	Single-study AOR 5.30 (1.50–19.10)
Abdominal obesity / waist circumference	1 / 1,150	Not pooled	Single-study HR 1.08 per 1 cm (1.06–1.10)

OR=odds ratio; HR=hazard ratio; CI=confidence interval; I^2=I-squared statistic. Pooled estimates were synthesised on the log scale from the most comparable adjusted ORs or HRs available and should therefore be interpreted as relative-effect summaries rather than strictly interchangeable causal odds ratios. Low physical activity and abdominal obesity could not be pooled because only one exact adjusted estimate was available for each determinant.

The clearest quantitative signal was observed for BMI, which showed a statistically significant pooled positive association with metabolic syndrome. Age, urban residence, female sex, and smoking all showed directionally informative but heterogeneous pooled estimates, with confidence intervals crossing the null for all except BMI. Low physical activity remained narratively important on the basis of the adolescent study from Ho Chi Minh City (AOR 5.3, 95% CI 1.5–19.1), while independent abdominal obesity could not be pooled because only one exact continuous estimate from the cohort study was available (HR 1.08 per 1 cm increase, 95% CI 1.06–1.10) [3–6].

3.6. Implications for prevention and control arising from the results

The results have direct implications for prevention and control in Vietnam. First, the clearest pooled quantitative signal concerned excess adiposity, as BMI showed a consistent positive summary association with metabolic syndrome and abdominal adiposity remained directionally important in the narrative synthesis. Second, the pooled estimates for age and urban residence, although heterogeneous, suggested that risk accumulates in older and more urbanised populations. Third, the high prevalence of component-level abnormalities such as hypertension, dyslipidaemia, and glucose-related disturbances supports strengthening routine screening for blood pressure, glucose, and lipid abnormalities, particularly in higher-risk adults and in women with excess adiposity [2–6].

At the national level, the STEPS 2021 findings reinforce this interpretation. With 59.0% of adults consuming insufficient fruit and vegetables and 22.2% not meeting physical activity recommendations, the Vietnamese metabolic-risk environment remains highly unfavourable. These results suggest that future control efforts should combine individual-level screening and counselling with broader community-, workplace-, and primary care-based interventions targeting diet, physical activity, and early metabolic risk detection [2].

Determinant-specific forest plots for the pooled meta-analyses are presented in Figures 2–6.

IV. DISCUSSION

This systematic review and meta-analysis shows that the most informative pooled upstream determinants of metabolic syndrome in Vietnam were higher BMI, older age, urban residence, female sex, and smoking status, although only BMI showed a statistically clear positive pooled association in the current harmonised dataset. Low physical activity and abdominal adiposity remained important narrative determinants, whereas hypertension, dyslipidaemia, and glucose-related abnormalities are better interpreted as component-level features of the metabolic syndrome phenotype rather than independent etiologic predictors [1–5].

One of the clearest findings of this review is the central role of excess adiposity. In the pooled analysis, BMI per 1 kg/m² increase was associated with a relative effect of 1.27 (95% CI 1.18–1.36; I^2=76.6%). This pooled signal is consistent with the Bac Giang study, in which obesity was associated with more than four-fold higher odds of metabolic syndrome (OR 4.14, 95% CI 1.45–11.85), and with the employee cohort, in which abdominal obesity was one of the main contributors to case identification [3–5].

A second major finding is the role of ageing as a risk amplifier. The pooled summary for age per 1-year increase was 1.04 (95% CI 0.996–1.09; I^2=93.6%), suggesting a positive but heterogeneous age-related gradient across Vietnamese studies. This direction is consistent with the large employee study, in which prevalence increased progressively with age, and with the Red River Delta analysis, in which age remained associated with metabolic syndrome in multivariable models [3,4].

The available evidence also supports a meaningful role for physical inactivity and related lifestyle factors, although the exact pooled synthesis could not yet be completed because only one directly comparable adjusted estimate was available. In adolescents from Ho Chi Minh City, those in the lowest physical activity group had higher odds of metabolic syndrome than those in the highest activity group (AOR 5.3, 95% CI 1.5–19.1), and the national STEPS 2021 survey showed that 22.2% of adults did not meet recommended physical activity levels and 59.0% consumed insufficient fruit and vegetables, indicating that the broader behavioural environment remains unfavourable for prevention [2,6].

Another important observation is the prominence of hypertension, dyslipidaemia, and glucose-related abnormalities as component-level correlates of metabolic syndrome. In the revised quantitative synthesis, these abnormalities were not pooled as independent predictors because they are incorporated into the diagnostic definition of metabolic syndrome under the IDF and NCEP ATP III frameworks. Treating them as etiologic exposures would generate tautological associations with inflated effect sizes, as illustrated by the unusually high crude OR reported for hypertension in one included study. Their descriptive prominence nevertheless supports integrated screening of blood pressure, glucose, and lipid abnormalities as part of routine cardiometabolic risk assessment in Vietnamese primary care and non-communicable disease services [4,6].

Our findings also highlight the importance of diagnostic and population heterogeneity. The pooled estimate for urban residence was positive but imprecise (1.80, 95% CI 0.94–3.47; I^2=72.2%), while the pooled estimate for female sex was highly heterogeneous (1.38, 95% CI 0.75–2.52; I^2=86.8%). Smoking showed an inverse but non-significant summary association (0.73, 95% CI 0.51–1.04; I^2=54.2%). These results suggest that the direction and magnitude of association for several determinants may vary according to diagnostic framework, study design, and target population [1–3].

Placed in a regional context, the pooled BMI effect observed in Vietnamese populations is broadly consistent with findings reported in other Asian settings, where higher adiposity has likewise emerged as one of the most consistent determinants of metabolic syndrome. Comparable patterns have been described in middle-income Asian populations undergoing rapid nutritional and lifestyle transition, where urbanisation, sedentary occupations, and dietary westernisation accompany rising central adiposity. Direct numerical comparisons across countries nevertheless remain limited by differences in diagnostic frameworks, age structure, and the relative weight of urbanisation-related lifestyle change, so the Vietnamese pooled estimates are best interpreted as regionally plausible rather than directly transferable.

This review has several important limitations. First, only two to three studies contributed to each pooled estimate, which limited precision and precluded meta-regression and subgroup analyses on the pooled scale. Second, ORs from cross-sectional studies were synthesised together with HRs from a cohort analysis on the log scale; because metabolic syndrome is not a rare outcome (prevalence 8–47% across included Vietnamese studies), these effect measures are not strictly interchangeable, and pooled estimates should therefore be interpreted as exploratory relative-effect summaries rather than as causally informative effect sizes. Third, statistical heterogeneity was substantial (I^2 54–94%) for every pooled determinant, suggesting that pooled point estimates may mask meaningful between-study variation. Fourth, formal assessment of publication bias was not feasible because no synthesis included ≥10 studies. Fifth, the predominance of cross-sectional designs (28/34) precludes causal inference, and several potentially important determinants—including low physical activity and independent abdominal obesity—could not be pooled because only one exact adjusted estimate was available for each. These limitations reinforce the need for prospective cohort studies, more standardised reporting of metabolic syndrome definitions, and better harmonisation of risk-factor measurement in future Vietnamese research [1–3].

Taken together, these findings have direct implications for prevention and control in Vietnam. Prevention should prioritise excess adiposity, particularly rising BMI and central adiposity, incorporate life-course physical activity promotion, and adopt risk-stratified screening with particular attention to older adults, urbanising populations, overweight or obese individuals, and women with increased metabolic vulnerability [2,4–6]. The high prevalence of component-level abnormalities—hypertension, dyslipidaemia, and glucose-related disturbances—supports strengthening routine screening for blood pressure, glucose, and lipid abnormalities, particularly in higher-risk adults and in women with excess adiposity [2–6]. Metabolic syndrome-related assessment should also be integrated more explicitly into primary care, especially alongside existing hypertension, diabetes, and lipid management programmes [6]. At the national level, the STEPS 2021 findings reinforce this interpretation: with 59.0% of adults consuming insufficient fruit and vegetables and 22.2% not meeting physical activity recommendations, future control efforts should combine individual-level screening and counselling with broader community-, workplace-, and primary care-based interventions targeting diet, physical activity, and early metabolic risk detection [2].

Despite the above limitations, this review provides both narrative and quantitative synthesis of the upstream determinants of metabolic syndrome in Vietnam. The current pooled results support a robust association for higher BMI and directionally consistent, though more heterogeneous, associations for age, urban residence, female sex, and smoking. Future prevention and control strategies should combine targeted screening, behavioural risk reduction, and integration into routine health services, while strengthening surveillance systems capable of tracking clustered metabolic risk over time [4,6].

V. CONCLUSION

In the currently harmonised Vietnamese evidence base, higher BMI showed the most consistent pooled positive association with metabolic syndrome, although this finding rests on only two studies. Older age, urban residence, female sex, and smoking showed more heterogeneous summary associations. Low physical activity and abdominal adiposity remained important narrative determinants but could not yet be pooled because only one exact adjusted estimate was available for each. Hypertension, dyslipidaemia, and glucose-related abnormalities are more appropriately characterised as components of the metabolic syndrome phenotype rather than as independent causal predictors. Future strategies in Vietnam should strengthen risk-stratified screening, particularly among older adults, urbanising and overweight populations, and metabolically vulnerable women, while integrating metabolic syndrome assessment into primary care and existing non-communicable disease programmes.

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Figures

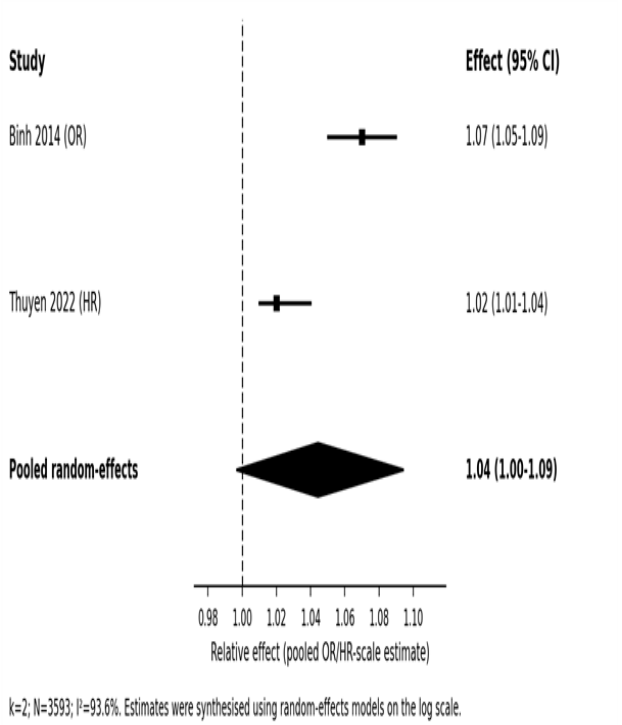

Figure 2. Forest plot of age (per 1-year increase) and metabolic syndrome in Vietnamese populations.

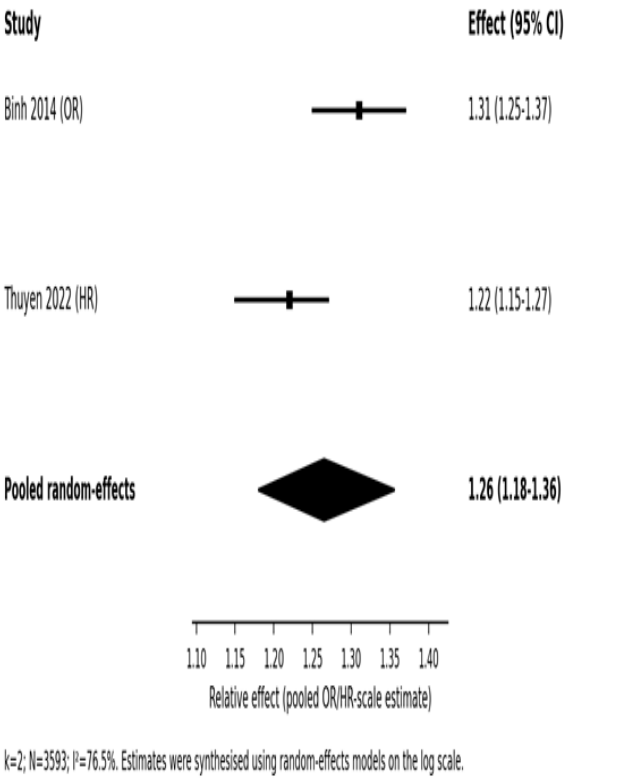

Figure 3. Forest plot of body mass index (per 1 kg/m² increase) and metabolic syndrome in Vietnamese populations.

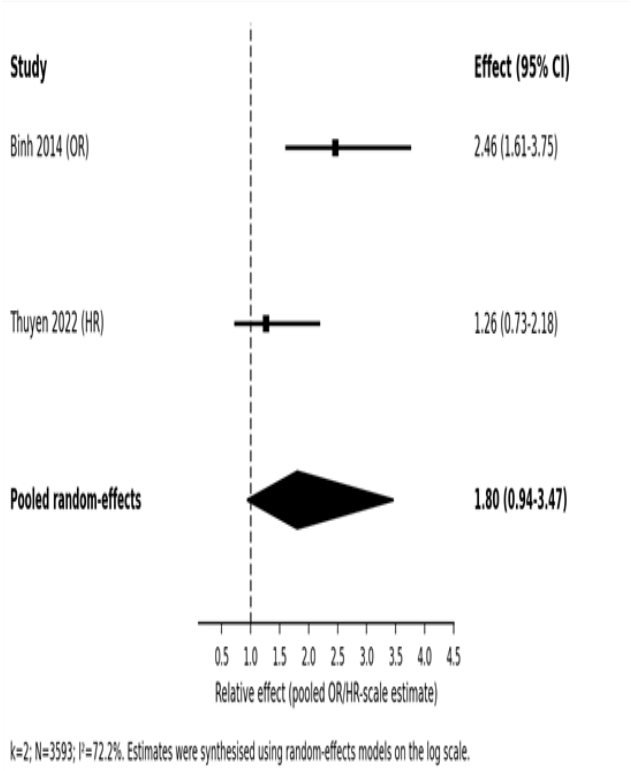

Figure 4. Forest plot of urban residence (urban vs rural) and metabolic syndrome in Vietnamese populations.

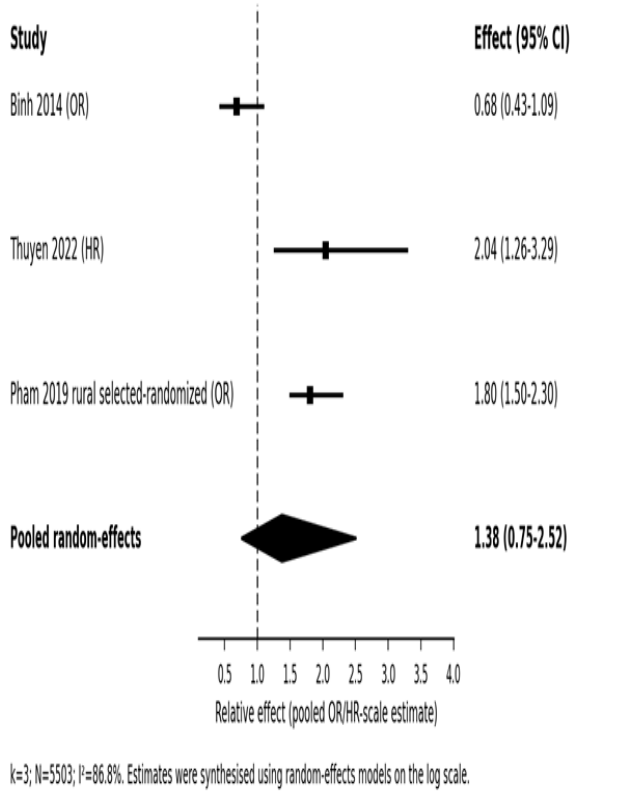

Figure 5. Forest plot of female sex (female vs male) and metabolic syndrome in Vietnamese populations.

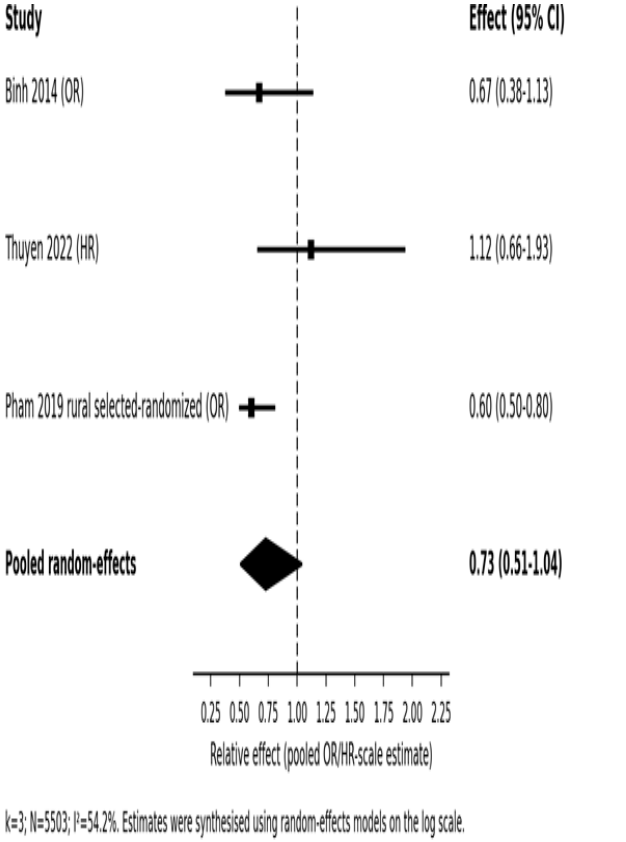

Figure 6. Forest plot of current/yes smoking versus none and metabolic syndrome in Vietnamese populations.