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# COMORBIDITY BURDEN AND CARDIOVASCULAR RISK STRATIFICATION USING SCORE2 AND SCORE2-OP IN RURAL PRIMARY CARE SETTINGS

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## ABSTRACT

**Background:** Cardiovascular disease is a leading cause of morbidity and mortality in Vietnam. A growing prevalence of comorbid illnesses further exacerbates this burden. Although risk stratification tools like SCORE2 and SCORE2-OP support early intervention, their use in primary care remains limited. This study assessed 10-year cardiovascular risk and its association with comorbidity and other factors in a rural Vietnamese hypertensive population. **Methods:** A cross-sectional study was conducted between January and September 2024 among 367 hypertensive patients aged 40 - 79 attending rural primary care facilities in Kon Tum province. SCORE2 and SCORE2-OP were used to estimate 10-year CVD risk. The Charlson Comorbidity Index (CCI) was utilized to evaluate the comorbidity burden. Sociodemographic data, clinical indicators, and self-care behaviours were collected. A multivariate logistic regression analysis was performed to identify factors linked to elevated or very high cardiovascular risk. **Results:** 64.0% of participants were classified as having high or very high cardiovascular risk. High-risk profiles were more common among older adults, males, those with central obesity, and individuals with poor weight management. In multivariate analysis, higher CCI scores were independently associated with increased cardiovascular risk (OR = 1.28, 95%CI: 1.01-1.62, p<0.05). Central obesity and elevated total cholesterol showed significant positive associations with higher risk, whereas higher levels of LDL-C and HDL-C were inversely associated (p<0.05). **Conclusion:** A substantial proportion of rural hypertensive adults were at high cardiovascular risk, underscoring robust primary care screening and prevention. Integrating comorbidity assessment and behavioural risk factors into routine CVD risk stratification, potentially through electronic health records, may enhance early identification and targeted interventions in low-resource settings.

***Keywords:*** *Cardiovascular risk, Hypertension, Primary care, Comorbidity burden, SCORE2*

## I. INTRODUCTION

Cardiovascular diseases (CVDs) represent the leading cause of death worldwide, with a tremendous burden in low- and middle-income countries (LMICs), where limited access to preventive services and healthcare infrastructure contributes to poor outcomes.[1] In Vietnam, like many LMICs, hypertension has emerged over the past two decades as a primary driver of cardiovascular morbidity and mortality.[1] Despite national efforts to improve hypertension control and integrate non-communicable disease (NCD) management into primary care, detection and

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management of cardiovascular risk factors remain insufficient.[2] Kon Tum, a mountainous province in the Central Highlands with a predominantly ethnic minority population, faces significant barriers to healthcare due to geography, infrastructure, and economics, highlighting gaps in early risk detection and management of high-risk individuals.[3]

Rather than occurring in isolation, hypertension is frequently accompanied by other chronic conditions, such as diabetes mellitus, chronic kidney disease, and chronic respiratory disease, which amplifies the risk of cardiovascular events. This co-occurrence with ageing populations is associated with poorer clinical outcomes, polypharmacy, reduced quality of life, and increased healthcare utilization.[4] In 2021, the European Society of Cardiology (ESC) introduced two updated risk prediction models, including SCORE2, designed for people aged 40-69, and SCORE2-Older Persons (SCORE2-OP), tailored for individuals aged 70 and above. These tools estimate 10-year cardiovascular risk based on age, sex, smoking status, systolic blood pressure, and non-HDL cholesterol and have been calibrated for use in diverse regions.[5] While widely adopted in clinical practice and regionally calibrated, these tools focus on traditional risk factors and do not explicitly incorporate the burden of chronic comorbidities.

Although most guidelines recommend a risk-based approach to CVD prevention, such models are often underutilized in routine primary care, particularly in rural settings with limited diagnostic capacity and training.[4] Few studies have examined how comorbidity burden influences cardiovascular risk estimation using SCORE2 or SCORE2-OP, especially in LMIC primary care contexts. This study aims to fill that gap by analyzing the association between comorbidity burden and cardiovascular risk, as estimated by SCORE2 and SCORE2-OP, among adults attending primary care facilities in Kon Tum province, Vietnam. This remote, ethnically diverse region provides an important context for understanding the real-world applicability of risk prediction tools in populations with high unmet health needs. Findings from this study could inform context-sensitive approaches to CVD risk assessment and support Vietnam's ongoing efforts to strengthen integrated NCD management in primary care.

## II. MATERIALS AND METHODS

### 2.1. Study design and settings

A cross-sectional study was conducted between January and September 2024 at commune health centres (CHCs) in rural areas of Kon Tum City and Đăk Hà District, Kon Tum Province, Vietnam. These primary care facilities were selected to represent underserved populations in both lowland and upland rural settings.

### 2.2. Study population

The study included adults aged 40-79 with diagnosed hypertension receiving care at selected CHCs. The required sample size was calculated at 402 participants, based on a 95% confidence level, a 5% margin of error, an estimated 51.6% prevalence of very high CVD risk from previous studies,[6] and a 5% non-response rate. A total of 367 participants completed the survey.

A two-stage sampling approach was used. CHCs were randomly selected in the first stage. In the second stage, eligible patients were randomly selected from the list of individuals currently managed for

hypertension at the selected CHCs. All participants provided written informed consent.

**2.3. Study Measurements**

Data were collected through structured face-to-face interviews at the CHCs. Ten-year cardiovascular risk was estimated using the SCORE2 (for individuals aged 40–69 years) and SCORE2-OP (for individuals aged 70-79) algorithms based on sex, age, systolic blood pressure, smoking status, and non-HDL cholesterol. The risk was categorized as low-to-moderate, high, or very high.[5] Comorbidity burden was assessed using the Charlson Comorbidity Index (CCI), grouped as mild (CCI 1-2), moderate (CCI 3-4), and severe (CCI ≥5). Anthropometric and clinical measurements included weight, height, waist circumference, blood pressure (average of two readings), and blood samples for glucose, triglycerides, total cholesterol, LDL-C, and HDL-C. According to Vietnam's Ministry of Health guidelines, blood pressure control was <140/90 mmHg. Additional variables included demographic information and self-reported lifestyle behaviours such as medication adherence, physical activity, low-salt diet, weight control, and alcohol consumption.

**2.3. Statistical analysis**

Data were entered and analyzed using EpiData version 3.1 and SPSS version 20.0. Chi-square tests assessed associations between 10-year cardiovascular risk and patient characteristics. Variables with $p < 0.20$ in bivariate analysis and factors identified in previous studies were included in multivariate logistic regression using the enter method.[3, 6] Odds ratios (ORs) along with 95% confidence intervals (CIs) were computed, with statistical significance determined at $p < 0.05$. A forest plot was utilized to illustrate the adjusted associations.

**2.4. Ethical consideration**

The study was approved by the Biomedical Ethics Committee of the University of Medicine and Pharmacy, Hue University (Approval No. H2023/340, dated June 2, 2023). All participants were fully informed about the study's objectives and procedures, provided written informed consent, and were assured of their right to withdraw without any consequences.

## III. RESULTS

Among 367 participants, 36.0% were classified as having low to moderate cardiovascular risk, 50.7% as high risk, and 13.3% as very high risk. The majority of males (88.9%) and individuals aged 60 years or older (80.8%) fell into the high or very high-risk group ($p < 0.001$) (Table 1). Among clinical indicators, uncontrolled blood pressure ($p < 0.001$), elevated waist circumference ($p = 0.03$), and higher levels of triglycerides ($p = 0.002$) and total cholesterol ($p = 0.007$) were significantly associated with increased cardiovascular risk.

Regarding self-care behaviours, non-adherence to weight management (73.1%), active smoking (97.4%), and at-risk alcohol consumption (87.2%) were strongly associated with high cardiovascular risk ($p < 0.01$). Although participants with moderate or high comorbidity burden (CCI≥2) had a higher proportion in the high-risk group (81.5%), the difference across CCI levels was not statistically significant ($p = 0.14$). No significant associations were observed with BMI, medication adherence, physical activity, low-salt diet, or illness perception (all $p > 0.05$).

*Table 1.* **Characteristics of Participants Stratified by 10-Year Cardiovascular Risk**

| Characteristics, n (%) | Overall | Estimate 10-year CVD risk | | p |
|---|---|---|---|---|
| | | Low-to-moderate risk | High - Very high risk | |
| **Sample size** | 367 | 132 (36.0) | 235 (64.0) | |
| **Gender** | | | | <0.001 |
| Female | 205 (55.9) | 114 (55.6) | 91 (44.4) | |
| Male | 162 (44.1) | 18 (11.1) | 144 (88.9) | |
| **Age** | | | | <0.001 |
| < 60 | 138 (37.6) | 88 (63.8) | 50 (36.2) | |
| ≥ 60 | 229 (62.4) | 44 (19.2) | 185 (80.8) | |
| **Charlson Comorbidity Index (CCI)** | | | | |
| No comorbidities | 185 (50.4) | 68 (36.8) | 117 (63.2) | 0.14 |
| Mild | 155 (42.2) | 59 (38.1) | 96 (61.9) | |
| Moderate and over | 27 (7.4) | 5 (18.5) | 22 (81.5) | |
| **BMI** | | | | |
| Underweight | 22 (6.0) | 6 (27.3) | 16 (72.7) | 0.56 |
| Normal weight | 157 (43.0) | 55 (35.0) | 102 (65.0) | |
| Overweight/ Obesity | 186 (51.0) | 71 (38.2) | 115 (61.8) | |
| **Waist circumference** | | | | |
| At risk | 280 (76.7) | 109 (38.9) | 171 (61.1) | 0.03 |
| Normal | 85 (23.3) | 22 (25.9) | 63 (74.1) | |
| **BP control** | | | | |
| Controlled | 203 (55.3) | 98 (48.3) | 105 (51.7) | <0.001 |
| Uncontrolled | 164 (44.7) | 34 (20.7) | 130 (79.3) | |
| **Fasting blood glucose, Mean (SD)** | 6.48 (3.0) | 6.51 (3.54) | 647 (2.66) | 0.9 |
| **Triglycerides, Mean (SD)** | 2.34 (2.57) | 1.90 (1.26) | 2.62 (3.09) | 0.002 |
| **Total cholesterol, Mean (SD)** | 5.17 (1.47) | 4.89 (1.09) | 5.32 (1.61) | 0.007 |
| **LDL-C, Mean (SD)** | 2.99 (1.02) | 2.88 (0.92) | 3.04 (1.05) | 0.14 |
| **HDL-C, Mean (SD)** | 1.39 (0.60) | 1.39 (0.57) | 1.39 (0.63) | 0.96 |
| **Medication adherence** | | | | |
| Adherent | 324 (88.3) | 122 (37.7) | 202 (62.3) | 0.07 |
| Non-adherent | 43 (11.7) | 10 (23.3) | 33 (76.7) | |
| **Physical Activity** | | | | |
| Adherent | 221 (60.2) | 78 (35.3) | 143 (64.7) | 0.74 |
| Non-adherent | 146 (39.8) | 54 (37.0) | 92 (63.0) | |
| **Low-salt Diet** | | | | |
| Adherent | 14 (3.8) | 6 (42.9) | 8 (57.1) | 0.58 |
| Non-adherent | 353 (96.2) | 126 (35.7) | 227 (64.3) | |
| **Weight management** | | | | |
| Adherent | 222 (60.5) | 93 (41.9) | 129 (58.1) | 0.003 |
| Non-adherent | 145 (39.5) | 39 (26.9) | 106 (73.1) | |
| **Active smoking** | | | | |
| No | 291 (79.3) | 130 (44.7) | 161 (55.3) | <0.001 |
| Yes | 76 (20.7) | 2 (2.6) | 74 (97.4) | |
| **At-risk alcohol drinking** | | | | |
| Not at risk | 250 (68.1) | 117 (46.8) | 133 (53.2) | <0.001 |
| At risk | 117 (31.9) | 15 (12.8) | 102 (87.2) | |

Figure 1 illustrates an apparent age-related increase in estimated 10-year cardiovascular risk. The proportion of participants classified as high or very high risk rose sharply from age 60 onward, accounting for over 80% in both the 60 - 69 and 70 - 79 age groups. In contrast, low to moderate risk was most common among participants under 60 years and declined markedly in older age groups. This shift in risk distribution was statistically significant ($p < 0.001$), with a strong linear trend confirming the progressive increase in cardiovascular risk with age.

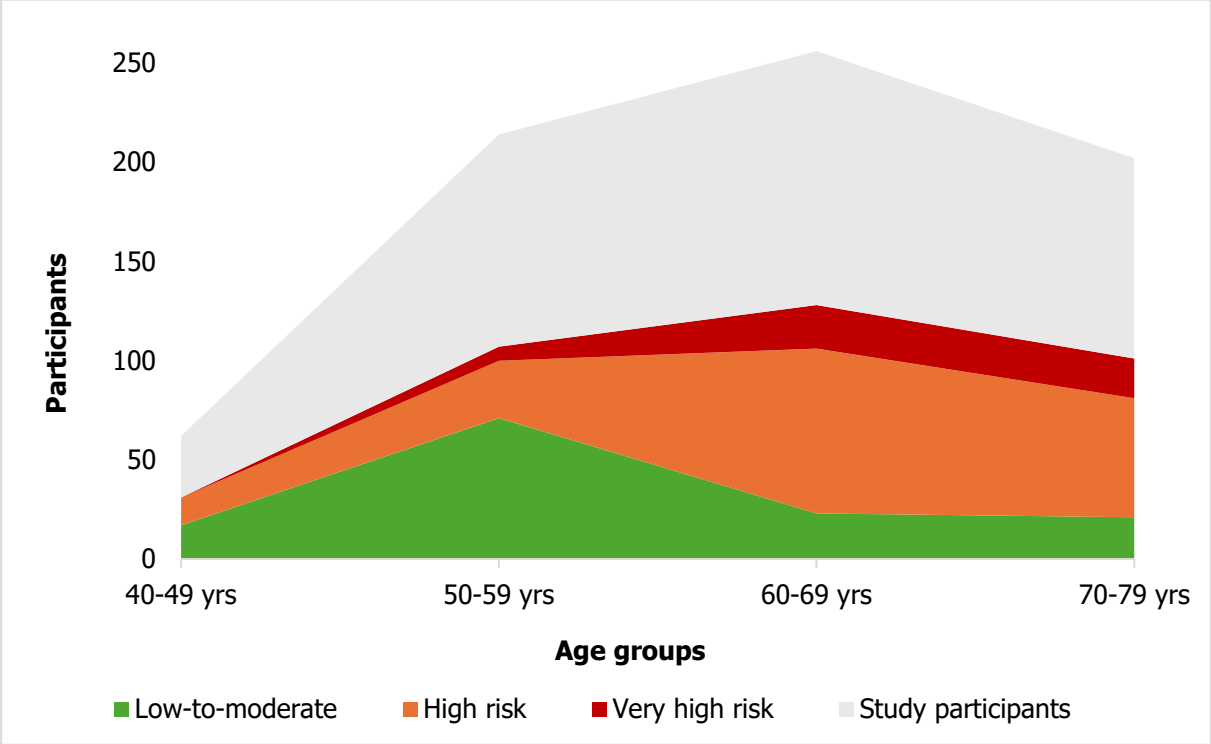


***Figure 1.*** **Age-stratified distribution of estimated 10-year CVD risk using SCORE2 and SCORE2-OP (n=367)**

The multivariate logistic regression analysis in Figure 2 identifies several factors significantly associated with high or very high estimated 10-year cardiovascular risk. A higher comorbidity burden (CCI) was associated with increased risk (OR = 1.28, 95% CI: 1.01-1.62, p = 0.04). Central obesity, defined by at-risk waist circumference, was also a significant predictor (OR = 2.12, 95% CI: 1.16-3.87, p = 0.02), as was elevated total cholesterol (OR = 2.45, 95% CI: 1.43-4.19, p = 0.001). Conversely, higher levels of LDL-C (OR = 0.40, p = 0.006) and HDL-C (OR = 0.51, p = 0.02) were negatively associated with high CVD risk. No significant associations were found for glucose levels or blood pressure categories. Among self-care behaviours, non-adherence to weight management was strongly associated with increased risk (OR = 2.5, 95% CI: 1.50-4.17, p < 0.001), while physical activity showed no significant effect.

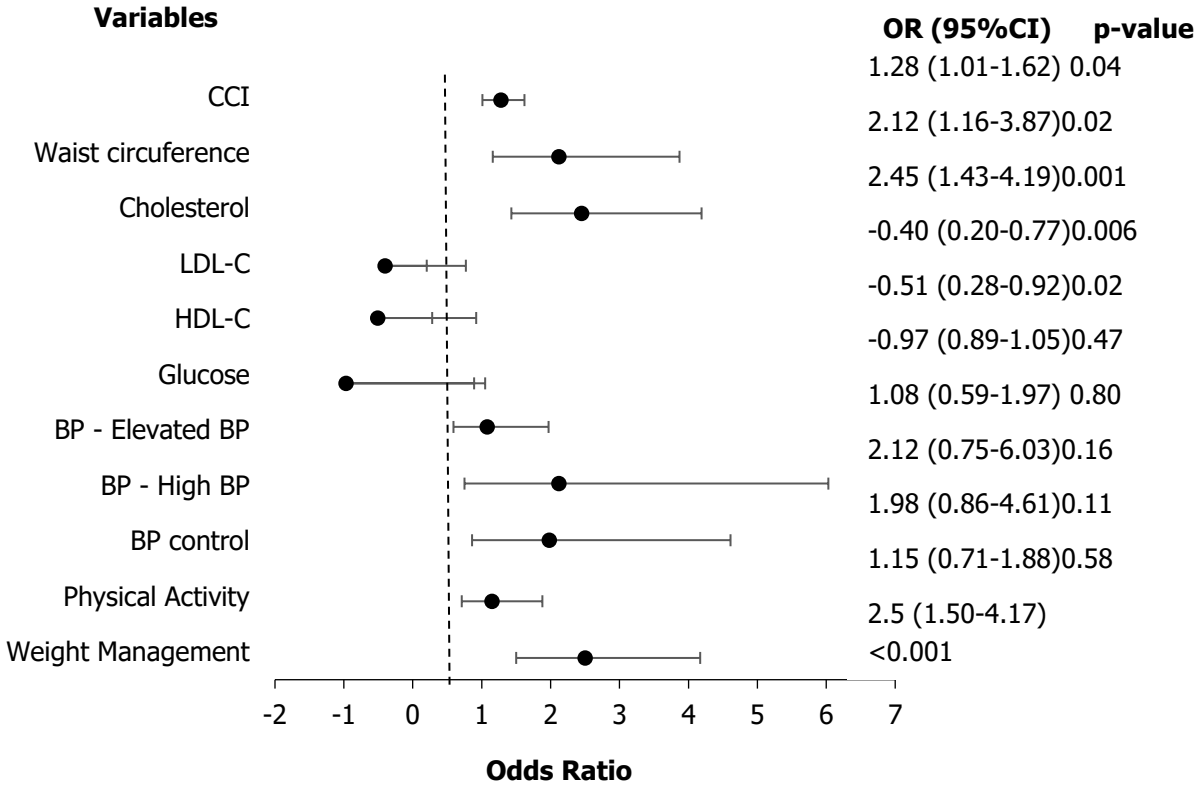


***Figure 2.*** **Factors associated with estimated 10-year cardiovascular risk among study participants**

*Note: CCI = Charlson Comorbidity Index; BP = Blood Pressure. For clarity, reference categories were omitted from the figure, including normal waist circumference, normal BP, uncontrolled BP, physical inactivity, and non-adherence to weight management. For continuous variables (e.g., CCI, glucose, HDL-C, LDL-C, total cholesterol), odds ratios (ORs) represent the change in risk per one-unit increase.*

## IV. DISCUSSION

**High cardiovascular risk burden in a rural population**

This study demonstrates a substantial burden of cardiovascular risk among adults attending primary care in Kon Tum province, with 64.0% of participants classified as having high or very high 10-year CVD risk. These findings align with a study in Thua Thien Hue province, which reported that 51.6% of participants had very high risk and 23.4% had high risk.[6] Both studies also observed a significantly higher CVD risk among men compared to women ($p < 0.001$), reinforcing gender as an important determinant in cardiovascular risk stratification in the Vietnamese context. The high prevalence of elevated risk observed in this rural and ethnically diverse population underscores a critical gap in early detection and prevention, particularly in settings with limited access to routine screening and care. The marked age-related increase in risk, where over 80% of adults aged 60 and above were in the high-risk category, is also consistent with existing literature [2] and

reinforces the predictive role of age in risk estimation models. Figure 1 further confirms a strong and statistically significant linear trend, supporting the urgency of implementing preventive interventions before individuals transition into older age brackets.

Recent studies have also highlighted the practical applicability of SCORE2 in rural and resource-limited primary care settings, where clinicians require simple yet robust tools to guide risk-based prevention strategies.[7] Our findings support this utility, as SCORE2/SCORE2-OP effectively stratified risk across age groups using easily obtainable clinical variables. In Vietnam, the Vietnam Society of Hypertension and national experts have recognized the importance of implementing validated cardiovascular risk tools, with SCORE2 and SCORE2-OP increasingly endorsed as suitable options for routine clinical use. To enhance their impact, SCORE2/SCORE2-OP should be integrated into hypertension and chronic disease management protocols at the commune and district levels. Digital or paper-based formats tailored to local workflows could support broader uptake and ensure frontline healthcare workers can implement risk-guided interventions effectively. Formal adoption into national primary care guidelines, such as for annual check-ups and cardiovascular screening campaigns, would improve early identification of high-risk individuals and promote more equitable CVD prevention in underserved areas.

**Clinical and behavioral predictors of elevated risk**

Several clinical indicators were independently associated with elevated cardiovascular risk. Central obesity (as measured by waist circumference) and elevated total cholesterol were significant predictors, aligning with previous research on CVD-related metabolic contributors.[2-4] The inverse association between HDL-C and CVD risk is well-established, but the observed negative association between LDL-C and risk was unexpected. This finding may be influenced by lipid-lowering treatment effects or residual confounding and should be interpreted cautiously until further validated in longitudinal studies.

Regarding blood pressure, although uncontrolled hypertension was significantly associated with higher risk in bivariate analysis, this relationship was not maintained in the multivariate model. This finding may indicate that blood pressure alone when adjusted for lipid and obesity factors, is insufficient to discriminate CVD risk within SCORE2 frameworks. Among self-care behaviours, non-adherence to weight management emerged as a strong and consistent predictor of high cardiovascular risk. Participants who did not actively control their weight had more than double the odds of being in the high-risk group, even after adjusting for metabolic factors. This emphasizes the crucial role of weight control in CVD prevention strategies, not only as a lifestyle goal but as a clinical target. In contrast, physical activity and dietary factors such as salt intake were not significantly associated with risk levels, which may reflect challenges in behaviour change implementation or the limitations of self-reported measures in primary care settings.

**Comorbidity burden and its role in risk prediction**

Comorbidity burden, measured by the Charlson Comorbidity Index (CCI), is increasingly recognized as a critical determinant of cardiovascular outcomes,

especially in ageing populations. In this study, while the bivariate analysis showed no significant association between comorbidity burden and risk classification, multivariate analysis revealed a statistically significant relationship, indicating that the effect of comorbidity may be masked when not adjusted for age and metabolic factors.

Beyond its physiological contributions, multimorbidity often complicates care due to factors such as treatment complexity, polypharmacy, and reduced adherence, which may further elevate cardiovascular risk yet are not captured by conventional scoring systems.[8] Although SCORE2 and SCORE2-OP are validated tools for risk prediction, they were developed based on general population cohorts and do not explicitly account for comorbid conditions. This limitation may lead to underestimation of risk in older or clinically complex individuals. Our findings suggest incorporating comorbidity indices such as the CCI into cardiovascular risk assessments could enhance their utility in primary care, especially in remote or underserved areas where multimorbidity is common and diagnostic resources are limited. Tailoring SCORE2-based tools to include comorbidity measures may offer more accurate and individualized risk stratification, supporting better-targeted prevention and management strategies in real-world settings.

**Implications for primary care in low-resource settings**

These findings have important implications for cardiovascular prevention in Vietnam and similar low-resource settings. In rural and mountainous areas, where preventive care infrastructure is limited and the prevalence of comorbidities is rising, there is a pressing need to strengthen cardiovascular risk screening and personalized intervention strategies at the primary care level. Beyond age and traditional risk factors, integrating multimorbidity, central obesity, and lifestyle-related risks into decision support tools could help primary care providers more accurately identify high-risk individuals and target limited resources accordingly. To improve practicality and scalability, SCORE2, SCORE2-OP, and CCI should be integrated into electronic health records or digital decision-support tools at the primary care level. This would help providers systematically assess risk, personalize treatment, and make timely decisions, especially in low-resource settings. Embedding these tools into routine workflows can enhance the early identification of high-risk individuals and better allocate preventive resources.

## V. CONCLUSION

This study reveals a high burden of cardiovascular risk among adults in a rural Vietnamese setting, with two-thirds classified as high or very high risk using SCORE2 and SCORE2-OP. In addition to traditional risk factors, comorbidity burden and poor weight management were independently associated with elevated risk. These findings highlight the need to enhance risk stratification by integrating clinical and behavioural complexity and support the practical use of SCORE2-based tools in primary care settings with limited resources.

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