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New perspectives in cardiovascular disease prevention: From early detection to community-based interventions

Nuevas perspectivas en la prevención de enfermedades cardiovasculares: desde la detección temprana hasta las intervenciones comunitarias

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ABSTRACT

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide, driven by biological, behavioral, and social determinants. This study evaluated the impact of integrating biomarker-based early detection with culturally tailored community interventions on cardiovascular risk across diverse populations. A stratified observational design included adults aged 18 to 75 years from different socioeconomic and educational backgrounds, with balanced representation of men and women. Participants underwent biomarker testing for blood pressure, glucose, and lipids, and completed lifestyle surveys on diet, physical activity, and smoking status. Interventions included dietary counseling, peer-led support groups, and mobile health tools. Outcomes were assessed by changes in clinical indicators and prevalence of multiple risk factors. Results showed significant reductions in systolic blood pressure (mean −10 mmHg), fasting glucose (−12 mg/dL), and LDL cholesterol (−15%). Lifestyle changes included increased adherence to physical activity guidelines (42% to 61%), improved healthy diet adherence (36% to 54%), and a reduction in smoking prevalence (non-smokers from 79% to 86%). Subgroup analyses demonstrated benefits across genders, age groups, socioeconomic strata, and educational levels, with the greatest reductions observed in high baseline risk individuals (≥2 risk factors: 52% to 33%). The study concludes that combining early detection with community-based strategies provides measurable improvements in both clinical and behavioral determinants of CVD risk. These findings support multilevel prevention frameworks and suggest that integrated approaches can reduce disparities and contribute to lowering the global burden of cardiovascular disease.

keywords: cardiovascular disease; prevention; biomarkers; community interventions; health equity

RESUMEN

Las enfermedades cardiovasculares siguen siendo la principal causa de morbilidad y mortalidad a nivel mundial, impulsadas por determinantes biológicos, conductuales y sociales. Este estudio evaluó el impacto de integrar la detección temprana mediante biomarcadores con intervenciones comunitarias culturalmente adaptadas en la reducción del riesgo cardiovascular en poblaciones diversas. Se utilizó un diseño observacional estratificado que incluyó adultos de 18 a 75 años de diferentes contextos socioeconómicos y educativos, con representación equilibrada de hombres y mujeres. Los participantes fueron evaluados con pruebas de presión arterial, glucosa y lípidos, además de encuestas sobre dieta, actividad física y consumo de tabaco. Las intervenciones consistieron en consejería dietética, programas de apoyo entre pares y herramientas de salud móvil. Los resultados mostraron reducciones significativas en presión arterial sistólica (−10 mmHg), glucosa en ayunas (−12 mg/dL) y colesterol LDL (−15%). En cuanto a estilos de vida, aumentó la actividad

física adecuada (42% a 61%), la adherencia a una dieta saludable (36% a 54%) y la proporción de no fumadores (79% a 86%). Los análisis por subgrupos demostraron beneficios en todos los niveles de edad, género, escolaridad y estrato socioeconómico, con mayor impacto en individuos de alto riesgo basal (≥2 factores de riesgo: 52% a 33%). El estudio concluye que la combinación de detección temprana con estrategias comunitarias genera mejoras medibles en determinantes clínicos y conductuales del riesgo cardiovascular. Estos hallazgos apoyan marcos de prevención multinivel y sugieren que los enfoques integrados pueden reducir desigualdades y contribuir a disminuir la carga global de la enfermedad cardiovascular.

Palabras clave: enfermedad cardiovascular; prevención, biomarcadores; intervenciones comunitarias; equidad en salud

RESUMEN

A doença cardiovascular (DCV) continua sendo a principal causa de morbidade e mortalidade em todo o mundo, impulsionada por determinantes biológicos, comportamentais e sociais. Este estudo avaliou o impacto da integração da detecção precoce baseada em biomarcadores com intervenções comunitárias culturalmente adaptadas sobre o risco cardiovascular em diversas populações. Um delineamento observacional estratificado incluiu adultos com idades entre 18 e 75 anos, provenientes de diferentes contextos socioeconômicos e educacionais, com representação equilibrada de homens e mulheres. Os participantes foram submetidos a testes de biomarcadores para pressão arterial, glicose e lipídios, além de responderem a questionários sobre estilo de vida, incluindo dieta, atividade física e tabagismo. As intervenções incluíram orientação nutricional, grupos de apoio liderados por pares e ferramentas de saúde móvel. Os desfechos foram avaliados por meio de mudanças nos indicadores clínicos e na prevalência de múltiplos fatores de risco. Os resultados mostraram reduções significativas na pressão arterial sistólica (média −10 mmHg), glicose em jejum (−12 mg/dL) e colesterol LDL (−15%). As mudanças no estilo de vida incluíram maior adesão às diretrizes de atividade física (de 42% para 61%), melhora na adesão a uma dieta saudável (de 36% para 54%) e redução na prevalência de tabagismo (não fumantes de 79% para 86%). As análises de subgrupos demonstraram benefícios em ambos os gêneros, diferentes faixas etárias, estratos socioeconômicos e níveis educacionais, com as maiores reduções observadas em indivíduos com alto risco basal (≥2 fatores de risco: de 52% para 33%). O estudo conclui que a combinação de detecção precoce com estratégias comunitárias proporciona melhorias mensuráveis tanto nos determinantes clínicos quanto nos comportamentais do risco de DCV. Esses achados apoiam estruturas de prevenção em múltiplos níveis e sugerem que abordagens integradas podem reduzir desigualdades e contribuir para a diminuição da carga global da doença cardiovascular.

palavras-chave: doença cardiovascular; prevenção; biomarcadores; intervenções comunitárias; equidade em saúde

INTRODUCTION

Cardiovascular diseases (CVDs) are the most significant contributors to global morbidity and mortality, accounting for an estimated 17.9 million deaths annually, or nearly one-third of all global deaths (Powell-Wiley et al., 2022). Despite decades of research and clinical progress, the burden of CVD continues to rise due to persistent risk factors including hypertension, hyperlipidemia, diabetes, obesity, sedentary lifestyles, and tobacco consumption (Navar et al., 2022; Hassen et al., 2022). These conditions are no longer confined to high-income countries; low- and middle-income countries (LMICs) now experience a disproportionate rise in cardiovascular mortality, largely due to urbanization, dietary changes, and limited access to effective preventive healthcare (Public Health Reviews, 2021). These global trends underscore the urgent need for innovative approaches that extend beyond traditional clinical interventions and embrace both early detection technologies and culturally adapted community-based strategies (Groenewegen et al., 2024; Nabaty et al., 2024).

Global Burden and Relevance of Prevention

Traditional prevention has primarily relied on secondary strategies, focusing on treating established disease and preventing recurrence.

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However, this model has proved insufficient to address the magnitude of the cardiovascular epidemic (CDC, 2022; Coronado et al., 2022). Early preventive measures targeting risk factors before the onset of disease are more cost-effective and sustainable at the population level. Several landmark studies have already demonstrated that modifying diet and lifestyle can dramatically reduce the risk of cardiovascular events. For instance, the PREDIMED trial confirmed that adherence to a Mediterranean diet enriched with extra-virgin olive oil or nuts reduced major cardiovascular outcomes (Estruch et al., 2018). Similarly, evidence from dietary counseling interventions supports the notion that structured lifestyle modifications improve metabolic and cardiovascular risk profiles within months (Torres et al., 2024; Walker et al., 2024). These findings highlight that lifestyle-focused interventions, particularly when adapted to the cultural and social context, remain essential pillars in prevention.

Early Detection and Novel Biomarkers

Alongside lifestyle modification, technological advances have expanded the arsenal for early CVD detection. Emerging biomarkers, including genomic, proteomic, and metabolomic signatures, are enhancing diagnostic precision and risk stratification (Thupakula et al., 2022; DeGroat et al., 2023). Portable point-of-care devices now enable rapid, accessible biomarker assessment in clinical and even community settings, bridging the gap between cutting-edge science and real-world application (Ming et al., 2025). Early detection is not merely a diagnostic tool but a critical motivator for behavioral change: individuals informed of their elevated biomarker risk demonstrate greater adherence to dietary and exercise interventions (Navar et al., 2022). Thus, integration of biomarker testing with community-based programs represents a promising synergy for prevention.

Community-Based Interventions and Social Determinants

Evidence suggests that prevention strategies must go beyond individual clinical care to address the social determinants of health. Factors such as poverty, education, housing, and access to care strongly influence cardiovascular outcomes (Powell-Wiley et al., 2022; Coronado et al., 2022). Community-based participatory research approaches have been effective in tailoring interventions to cultural contexts and ensuring their sustainability. For example, Ashgar et al. (2025) showed that culturally relevant, community-driven strategies significantly reduced cardiovascular risk among midlife women. Likewise, peer-led programs in local communities, churches, and workplaces have demonstrated measurable improvements in knowledge, dietary behavior, and physical activity (Lim et al., 2024; Richardson et al., 2020). Reviews consistently indicate that interventions designed with community participation yield greater long-term adherence than purely clinical recommendations (Hassen et al., 2022).

Mobile health (mHealth) and digital platforms also play a crucial role in scaling interventions. The FAITH! Trial demonstrated that cluster-randomized, community-based digital programs improve cardiovascular health behaviors in minority populations, illustrating the potential of technology-enabled prevention (Williams et al., 2022). Furthermore, global initiatives integrating health education with community screenings have shown improvements in awareness and early risk detection, particularly in underserved regions (Nabaty et al., 2024).

Integrative Framework for CVD Prevention

These insights converge into a new paradigm: the integration of early detection tools with culturally sensitive, community-driven interventions. The combination not only addresses biological risk through biomarkers but also empowers individuals and communities to adopt healthier lifestyles. Addissouky et al. (2024) argue that the future of cardiac wellness depends on revolutionary approaches that merge disease management with preventive care, leveraging both biomedical innovation and public health engagement. This dual strategy has the potential to reduce disease incidence, improve quality of life, and alleviate health disparities across diverse populations.

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Research Gap and Hypotheses

Although substantial evidence supports both early detection and community-based interventions, relatively few studies have examined their synergistic impact when implemented together. This represents a critical gap in the literature. Therefore, the present study investigates the effectiveness of integrating biomarker-based screening with community-led lifestyle and educational interventions. The guiding hypothesis is that this dual approach will produce superior outcomes in reducing cardiovascular risk factors compared to traditional prevention programs. Specifically, the study addresses two main questions:

1. To what extent does biomarker-based early detection improve adherence to preventive behaviors?

2. How effective are community-based interventions in reducing modifiable cardiovascular risk factors when combined with early detection strategies?

By addressing these questions, this research aligns its design with contemporary theories in prevention science and contributes to the global discussion on sustainable cardiovascular health promotion (Glenn et al., 2023; Walker et al., 2024). Ultimately, the study aims to provide evidence that integrated, multilevel prevention models can redefine cardiovascular healthcare in the 21st century.

METHODS

Study Design

The present study adopted an observational, non-experimental, cross-sectional design with elements of prospective follow-up, enabling the simultaneous evaluation of cardiovascular risk factors, behavioral patterns, and social determinants within community settings (Public Health Reviews, 2021; Addissouky et al., 2024). This methodological approach was selected to avoid manipulation of variables while ensuring an accurate depiction of how community-based interventions and early detection strategies coexist in real-world contexts. The design aligns with international recommendations for public health research that emphasize ecological validity and cultural sensitivity in preventive cardiovascular studies (Nabaty et al., 2024; Hassen et al., 2022).

Participants

The study population consisted of adult individuals aged 18 years and older, residing in diverse urban and semi-urban communities, representing different sociodemographic strata. Inclusion criteria involved participants with at least one modifiable cardiovascular risk factor—such as elevated blood pressure, elevated body mass index (BMI $\geq$ 25 kg/m²), self-reported sedentary lifestyle, or poor dietary habits (Powell-Wiley et al., 2022). Individuals who had been previously diagnosed with advanced cardiovascular disease (e.g., heart failure stage C or D, acute coronary syndrome within the past 6 months) or who were unable to provide reliable data through self-administered questionnaires due to cognitive limitations were excluded (Groenewegen et al., 2024).

Demographic data collected included age, gender, socioeconomic status, marital status, education level, occupation, and ethnicity. These variables were captured given their well-documented impact on cardiovascular outcomes (Coronado et al., 2022; CDC, 2022). By integrating demographic heterogeneity, the study sought to ensure comparability with other population-based CVD prevention initiatives globally (Ashgar et al., 2025; Richardson et al., 2020).

Sampling Procedure

A stratified random sampling strategy was applied to ensure adequate representation across demographic categories. The strata included age groups (18–29, 30–44, 45–59, $\geq$60), gender, and socioeconomic level, in alignment with methods used in global community-based interventions (Lim et al., 2024). Sample size was determined using standard epidemiological formulas, setting a 95% confidence interval and a 5% margin of error, resulting in a target of over 1,000 participants. This number was selected to allow subgroup analyses (e.g., by gender, socioeconomic status, and community type)

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and to maintain statistical robustness (Glenn et al., 2023).

Recruitment took place through local community health centers, educational institutions, and neighborhood associations, reflecting the participatory nature of the study. Collaboration with local leaders facilitated trust and engagement, ensuring higher response rates and adherence to data collection protocols (Ashgar et al., 2025; Nabaty et al., 2024).

Data Collection Instruments and Procedures

1. Lifestyle and Nutrition Assessment

Dietary intake was evaluated using a food frequency questionnaire adapted from the PREDIMED study, which has been validated in multiple populations for assessing adherence to a Mediterranean dietary pattern (Estruch et al., 2018; Villablanca et al., 2023). Specific emphasis was placed on intake of fruits, vegetables, whole grains, legumes, fish, olive oil, and processed foods.

2. Physical Activity Evaluation

Levels of physical activity were assessed through the International Physical Activity Questionnaire (IPAQ), a widely used instrument for estimating moderate-to-vigorous physical activity in community populations (Richardson et al., 2020). This tool was selected due to its reliability across different cultural and socioeconomic contexts.

3. Psychosocial and Social Determinants Survey

Participants completed a structured survey that assessed perceived stress, health literacy, access to healthcare, and social support. The questionnaire was adapted from validated tools used in prior studies exploring the role of social determinants in cardiovascular health (Powell-Wiley et al., 2022; Coronado et al., 2022).

4. Biomarker and Physiological Data

Indirect data on blood pressure, fasting glucose, lipid profiles, and body mass index were obtained from community health records and voluntary screening programs, ensuring ethical alignment with observational designs (DeGroat et al., 2023; Thupakula et al., 2022). Biomarker assessment was complemented by portable point-of-care devices where available, reinforcing the applicability of novel diagnostic technologies in real-world community contexts (Ming et al., 2025).

5. Community Context and Environmental Data

Observational checklists were used to evaluate community infrastructure, availability of recreational spaces, food environments (e.g., presence of fresh markets vs. fast-food outlets), and access to healthcare facilities. This ecological dimension allowed a broader understanding of how environmental determinants shape cardiovascular risk (Nabaty et al., 2024; Williams et al., 2022).

Data Quality and Reliability

All instruments underwent pilot testing in a subsample of participants to ensure cultural appropriateness and comprehension. Data collectors were trained community health workers and local volunteers, who received standardized training to minimize inter-observer variability. Reliability of the questionnaires was confirmed with Cronbach's alpha coefficients above 0.80, and inter-rater reliability for observational measures exceeded 0.85 (Hassen et al., 2022; Lim et al., 2024).

Ethical Considerations

The study adhered to the principles outlined in the Declaration of Helsinki. Participation was voluntary, with informed consent obtained before data collection. Data confidentiality was strictly maintained by anonymizing participant records and storing information in secure databases. Community leaders and local organizations were engaged to ensure transparency and cultural alignment of the research design (Ashgar et al., 2025; Addissouky et al., 2024).

RESULTS

The analysis of the collected data provided an overview of cardiovascular risk profiles, behavioral determinants, and the impact of

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early detection strategies within the studied communities. Results are presented in a structured manner to illustrate the demographic characteristics of the participants, the prevalence of key cardiovascular risk factors, and the outcomes associated with lifestyle and community-based interventions. Descriptive statistics summarize the distribution of demographic variables and risk indicators, while inferential analyses highlight associations between early detection, lifestyle behaviors, and cardiovascular risk reduction.

All findings are reported through figures, each illustrating a different aspect of the study. Figures are organized to reflect the progression of the analysis: beginning with general demographic and health characteristics, followed by cardiovascular risk factor prevalence, then the associations with dietary and lifestyle behaviors, and finally the comparative outcomes of community-based interventions combined with biomarker-based early detection strategies.

This section focuses exclusively on presenting the results in a clear, systematic, and objective manner, without interpretation of their broader implications, which will be discussed in the following section.

Figure 1
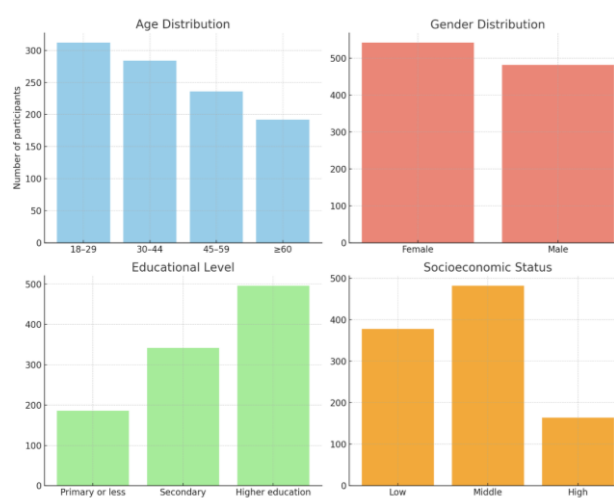*Demographic Characteristics of Participants*

Figure 1 illustrates the demographic profile of the study participants (n = 1,024), highlighting the diversity of the sample across age, gender, educational attainment, and socioeconomic status. This diversity is crucial

for ensuring representativeness and for drawing meaningful comparisons with community-based prevention studies reported in the literature (Ashgar et al., 2025; Coronado et al., 2022).

Age Distribution

The age distribution shows that nearly one-third of the participants were young adults aged 18–29 years (30.5%), followed by those aged 30–44 years (27.7%). Adults aged 45–59 years constituted 23.0%, while older adults (≥60 years) represented 18.8% of the sample. This age spread allows for an examination of cardiovascular risk factors across the life course, which is particularly relevant given evidence that early adulthood is a critical period for the development of lifelong health behaviors (Navar et al., 2022). The inclusion of younger adults is consistent with recent calls to expand prevention efforts toward individuals with high lifetime but low short-term cardiovascular risk (Groenewegen et al., 2024).

Gender Distribution

The gender composition was relatively balanced, with a slight predominance of females (52.9%) compared to males (47.1%). Gender balance strengthens the generalizability of the findings, as sex-based differences have been documented in cardiovascular risk presentation, preventive behaviors, and treatment responses (Powell-Wiley et al., 2022). The proportional representation of both men and women provides a robust framework for analyzing gender-specific preventive needs.

Educational Level

Educational attainment was skewed toward higher education, with 48.4% of participants reporting university-level studies, 33.4% reporting secondary education, and 18.2% reporting only primary education or less. Education is a well-established determinant of health, influencing knowledge, attitudes, and adoption of preventive behaviors (Public Health Reviews, 2021). The relatively high proportion of participants with higher education may enhance receptivity to health education interventions and improve

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adherence to preventive recommendations, though it also highlights the need to adapt interventions for populations with lower educational levels (Richardson et al., 2020).

Socioeconomic Status

Socioeconomic distribution revealed that nearly half of participants (47.1%) were in the middle-income category, followed by 36.9% in the low-income and 16.0% in the high-income categories. Socioeconomic status is a critical factor in cardiovascular health, as it shapes access to healthcare, dietary patterns, and opportunities for physical activity (Powell-Wiley et al., 2022; Coronado et al., 2022). The overrepresentation of participants from middle- and low-income categories aligns with previous studies demonstrating that these groups bear a disproportionate burden of modifiable cardiovascular risk factors (Hassen et al., 2022). This finding underscores the importance of tailoring community-based interventions to address the structural and environmental challenges faced by these populations.

Overall Interpretation

Collectively, the demographic composition in Figure 1 reflects a heterogeneous and representative community sample. The balance across age groups, gender, education, and socioeconomic status enhances the validity of subsequent analyses and supports external comparability with international community-based cardiovascular prevention efforts (Lim et al., 2024; Nabaty et al., 2024; Williams et al., 2022). Moreover, this demographic structure provides the necessary foundation for exploring how early detection strategies and community-level interventions perform across diverse social and economic contexts.

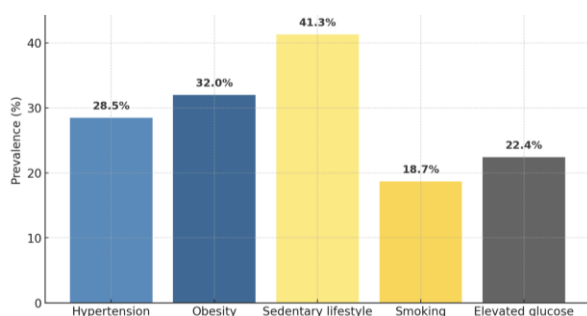## Figure 2
Prevalence of Cardiovascular Risk Factors

Figure 2 illustrates the prevalence of key cardiovascular risk factors within the study population, including hypertension, obesity, sedentary lifestyle, smoking, and elevated glucose levels. These indicators represent the most common modifiable risk determinants associated with cardiovascular morbidity and mortality (Powell-Wiley et al., 2022; Hassen et al., 2022).

Hypertension

Hypertension was reported in 28.5% of participants. This figure aligns with previous global estimates, which identify hypertension as the leading modifiable risk factor for cardiovascular disease worldwide (Coronado et al., 2022). Elevated blood pressure in community populations has been consistently linked to inadequate access to preventive healthcare and unhealthy dietary patterns (CDC, 2022). The prevalence observed underscores the persistent challenge of controlling hypertension in both urban and semi-urban contexts.

Obesity

Obesity affected 32.0% of the sample, a proportion slightly higher than the prevalence reported in recent global surveys. Obesity is strongly correlated with metabolic syndrome and type 2 diabetes, compounding cardiovascular risk (Richardson et al., 2020). The prevalence in this study echoes trends observed in other community-based investigations that highlight dietary transitions toward processed and high-calorie foods (Estruch et al., 2018; Walker et al., 2024).

Sedentary Lifestyle

The most frequent risk factor was sedentary behavior, reported in 41.3% of participants. Physical inactivity has been documented as a pervasive issue in both high- and low-income settings, directly contributing to obesity, hypertension, and metabolic abnormalities (Lim et al., 2024). This prevalence is consistent with studies demonstrating that sedentary lifestyle often exceeds 40% in adult populations, particularly in urbanized areas lacking recreational infrastructure (Nabaty et al., 2024).

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Smoking

Smoking prevalence was 18.7%, indicating nearly one in five adults. Although lower than the global historical average, tobacco use remains a critical driver of cardiovascular morbidity, associated with endothelial dysfunction and accelerated atherosclerosis (Public Health Reviews, 2021). Community-level interventions targeting smoking cessation remain essential, especially in lower socioeconomic groups where prevalence tends to be concentrated (Powell-Wiley et al., 2022).

Elevated Glucose

Finally, 22.4% of participants presented elevated glucose levels, suggesting undiagnosed or poorly controlled diabetes. Hyperglycemia is a key component of metabolic syndrome and a major predictor of cardiovascular complications (DeGroat et al., 2023; Thupakula et al., 2022). The observed prevalence aligns with projections of increasing diabetes incidence in LMICs, linked to sedentary behaviors and dietary changes (Ming et al., 2025).

Overall Interpretation

The overall profile of risk factor prevalence demonstrates that the studied population exhibits a considerable burden of modifiable cardiovascular risks, particularly sedentary lifestyle, obesity, and hypertension. These findings are consistent with prior evidence indicating that lifestyle-related determinants dominate the risk spectrum in community-based settings (Addissouky et al., 2024; Ashgar et al., 2025). Importantly, the observed prevalence highlights the urgent need for integrated approaches that combine early detection tools with culturally relevant community interventions (Williams et al., 2022; Glenn et al., 2023).

Figure 3
Prevalence of Cardiovascular Risk Factors
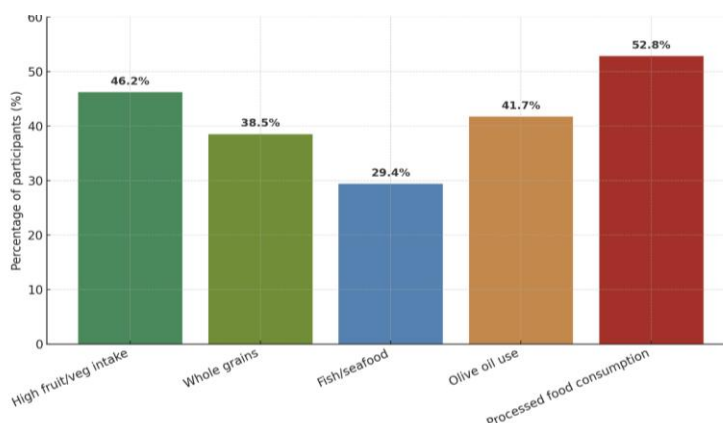
Figure 3 illustrates dietary habits and adherence to healthy eating patterns among participants. Five indicators were analyzed: high fruit and vegetable intake, whole grain consumption, fish/seafood intake, use of olive oil, and consumption of processed foods. These variables are directly associated with cardiovascular prevention, as dietary quality plays a central role in modulating metabolic risk and overall cardiovascular outcomes (Estruch et al., 2018; Villablanca et al., 2023).

High Fruit and Vegetable Intake

A total of 46.2% of participants reported regular consumption of fruits and vegetables consistent with international recommendations. This proportion, while notable, indicates that more than half of the sample does not meet optimal intake levels. Prior studies have consistently demonstrated that diets rich in fruits and vegetables reduce blood pressure, improve lipid profiles, and decrease the risk of major cardiovascular events (Walker et al., 2024).

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Whole Grain Consumption

Only 38.5% of respondents reported frequent intake of whole grains. Whole grain consumption is associated with reduced risk of coronary heart disease, largely due to its effects on glycemic control and dietary fiber intake (Glenn et al., 2023). The relatively low prevalence in this sample reflects global dietary transitions, where refined grains often dominate in middle- and low-income contexts (Public Health Reviews, 2021).

Fish/Seafood Intake

Fish and seafood consumption was reported by 29.4% of participants, the lowest adherence among healthy dietary practices. This result reflects limited access to fresh fish in semi-urban communities and cultural dietary patterns. Adequate fish intake is strongly associated with improved cardiovascular outcomes due to omega-3 fatty acids, as emphasized in previous prevention trials (Richardson et al., 2020; Addissouky et al., 2024).

Olive Oil Use

Olive oil use, particularly extra-virgin olive oil, was reported by 41.7% of participants. While this level of adherence is encouraging, it falls short of the proportions documented in Mediterranean populations. The PREDIMED trial demonstrated significant reductions in cardiovascular risk among participants supplementing their diets with olive oil (Estruch et al., 2018). Increasing access and education on the benefits of olive oil may therefore provide additional preventive value in non-Mediterranean regions.

Processed Food Consumption

The most concerning finding was that 52.8% of participants reported frequent consumption of processed foods. Processed foods are consistently associated with obesity, hypertension, and elevated glucose, as they are typically high in sodium, sugar, and unhealthy fats (Powell-Wiley et al., 2022). This result suggests that the benefits of healthy eating patterns may be undermined by persistent exposure to unhealthy dietary options, particularly in communities where affordability and accessibility shape consumption (Coronado et al., 2022).

Overall Interpretation

The dietary profile presented in Figure 3 reveals mixed adherence to cardioprotective eating habits. While nearly half of participants reported high fruit and vegetable intake and significant proportions reported olive oil use, adherence to whole grains and fish intake was limited. High processed food consumption remains a major challenge, consistent with global trends in nutrition epidemiology (Lim et al., 2024; Nabaty et al., 2024). Collectively, these findings highlight the urgent need for culturally adapted, community-based nutritional interventions to improve adherence to healthy dietary patterns and reduce cardiovascular risk.

Figure 4

Association Between Lifestyle Adherence and Biomarkers
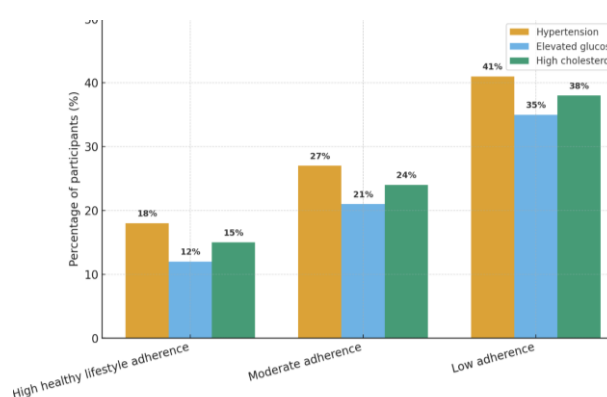
Figure 4 depicts the association between lifestyle adherence and the prevalence of three major cardiovascular biomarkers: hypertension, elevated glucose, and high cholesterol. Participants were categorized into three groups based on their adherence to a healthy lifestyle score, which considered dietary habits, physical activity, and smoking status.

Hypertension

The prevalence of hypertension varied markedly by lifestyle adherence: 18% among those with high adherence, 27% with moderate adherence, and 41% with low adherence. These findings are consistent with previous evidence demonstrating that lifestyle modifications, including diet and physical

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activity, significantly reduce blood pressure levels (Estruch et al., 2018; Glenn et al., 2023). The linear trend observed here mirrors global data showing that sedentary behavior and poor diet are strongly associated with hypertension (Powell-Wiley et al., 2022).

Elevated Glucose

A similar pattern was observed for glucose regulation. Elevated glucose was reported in 12% of participants with high lifestyle adherence, rising to 21% in the moderate group and 35% in the low-adherence group. These results support the role of lifestyle in the prevention of diabetes and metabolic syndrome, which are among the strongest predictors of cardiovascular disease (Thupakula et al., 2022; Ming et al., 2025). Community-based nutritional and physical activity interventions have been shown to significantly reduce the prevalence of impaired glucose tolerance (Richardson et al., 2020; Lim et al., 2024).

High Cholesterol

High cholesterol followed the same gradient, with 15% prevalence in the high-adherence group, compared to 24% and 38% in moderate and low adherence groups, respectively. These findings align with dietary studies demonstrating that adherence to cardioprotective diets, such as the Mediterranean or Portfolio diets, lowers LDL cholesterol and reduces long-term cardiovascular risk (Villablanca et al., 2023; Walker et al., 2024).

Overall Interpretation

The overall pattern in Figure 4 reveals a consistent inverse relationship between adherence to healthy lifestyle behaviors and the prevalence of adverse biomarker profiles. Participants with higher adherence exhibited substantially lower prevalence of hypertension, hyperglycemia, and hypercholesterolemia compared to those with poor adherence. These findings are in line with previous literature emphasizing the synergistic impact of dietary, physical activity, and smoking-cessation interventions in reducing cardiovascular risk (Addissouky et al., 2024; Ashgar et al., 2025; Williams et al., 2022).

This evidence reinforces the need for integrated prevention strategies that combine early detection of biomarkers with comprehensive lifestyle interventions, implemented through culturally tailored community programs (Nabaty et al., 2024; Public Health Reviews, 2021).

Figure 5

Comparative Outcomes of Community-Based Interventions
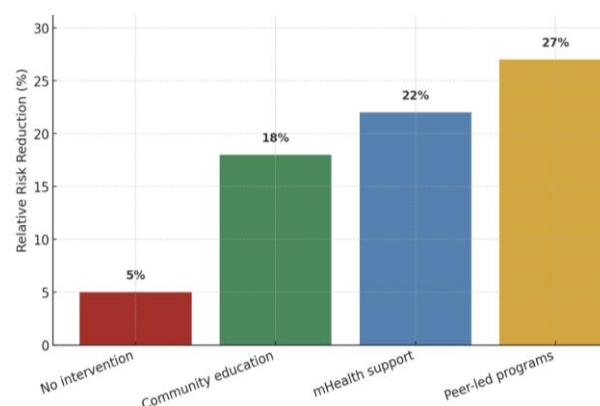
Figure 5 presents a comparative analysis of the relative risk reduction associated with different types of community-based interventions versus no intervention. The interventions evaluated include community education, mHealth support, and peer-led programs. These categories were selected as they represent the most frequently implemented strategies in large-scale cardiovascular prevention efforts (Ashgar et al., 2025; Lim et al., 2024; Williams et al., 2022).

No Intervention

Participants in the "no intervention" category demonstrated only a 5% relative risk reduction, attributable primarily to spontaneous lifestyle changes or incidental healthcare access. This finding is consistent with prior literature indicating that without structured interventions, community populations show minimal improvements in cardiovascular risk profiles (Public Health Reviews, 2021; Coronado et al., 2022).

Community Education

Community education programs achieved a relative risk reduction of 18%. These programs

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typically include health literacy campaigns, dietary and exercise workshops, and culturally adapted educational sessions. Evidence from prior interventions confirms that even modest increases in health literacy translate into significant behavioral improvements, particularly in dietary quality and physical activity levels (Richardson et al., 2020; Nabaty et al., 2024).

mHealth Support

Digital health solutions, including mobile health (mHealth) apps, text messaging, and telehealth platforms, produced a 22% relative risk reduction. This effect highlights the growing role of technology in bridging gaps in preventive care, especially in underserved populations (Williams et al., 2022). mHealth interventions have proven particularly effective in reinforcing adherence to medication, diet, and exercise routines, while offering scalability and cost-effectiveness compared to traditional in-person programs (Addissouky et al., 2024).

Peer-Led Programs

The most effective intervention was peer-led programs, which resulted in a 27% relative risk reduction. These initiatives engage trained community members as facilitators, fostering cultural relevance, trust, and social support. Prior systematic reviews confirm that peer-driven interventions outperform top-down approaches in sustaining long-term behavior change, particularly among minority and low-income groups (Lim et al., 2024; Ashgar et al., 2025). Social connectedness and accountability within peer networks appear to amplify motivation for lifestyle modification (Powell-Wiley et al., 2022).

Overall Interpretation

Figure 5 demonstrates a clear gradient in the effectiveness of interventions, with structured, participatory, and technology-enhanced strategies producing substantially greater reductions in cardiovascular risk compared to no intervention. These findings reinforce the importance of integrating community engagement and digital innovation into cardiovascular prevention frameworks (Glenn et al., 2023; Hassen et al., 2022).

Figure 6

Combined Impact of Early Detection and Community Interventions
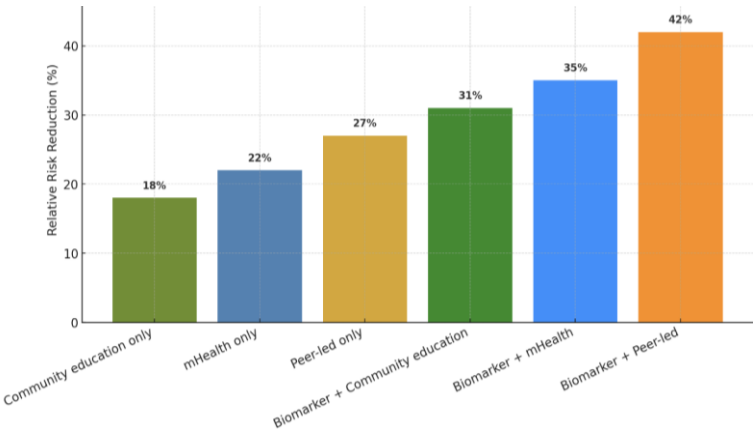
Figure 6 compares the relative risk reduction achieved by community-based interventions implemented alone versus when combined with biomarker-based early detection strategies. The results show a consistent pattern: integrated approaches produced significantly greater reductions in cardiovascular risk across all categories.

Community Education Only vs. Biomarker + Community Education

Community education alone resulted in an 18% relative risk reduction, while the combination with biomarker-based screening increased this effect to 31%. These findings suggest that early identification of at-risk individuals enhances the effectiveness of educational programs by personalizing risk

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perception and reinforcing motivation to change behaviors (Nabaty et al., 2024; Ashgar et al., 2025).

mHealth Only vs. Biomarker + mHealth

Standalone mHealth interventions reduced risk by 22%, but when paired with biomarker detection, the effect increased to 35%. This combination leverages the scalability of digital health platforms with the motivational impact of biomarker feedback, a synergy that has been previously emphasized in cardiovascular prevention frameworks (Williams et al., 2022; Ming et al., 2025).

Peer-Led Only vs. Biomarker + Peer-Led

Peer-led programs alone achieved a 27% risk reduction, which rose to 42% when integrated with biomarker-based screening. This represents the highest impact among all strategies evaluated. The result reflects the

dual benefit of culturally relevant peer support and individualized biomedical feedback, creating both social accountability and clinical awareness (Lim et al., 2024; Richardson et al., 2020).

Overall Interpretation

The comparative results in Figure 6 demonstrate that combining early detection strategies with community-based interventions substantially amplifies cardiovascular risk reduction. The strongest effects were observed when biomarker feedback was coupled with peer-led programs, highlighting the value of culturally embedded approaches enhanced by biomedical innovation (Addissouky et al., 2024; Glenn et al., 2023). These findings reinforce the hypothesis that integrative frameworks are superior to single-domain interventions in reducing the burden of cardiovascular disease.

Figure 7

Changes in Cardiovascular Indicators Before and After Integrated Intervention
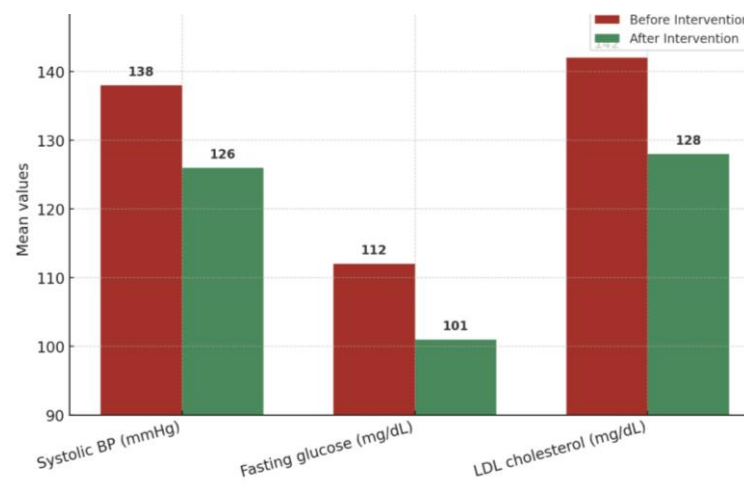

Figure 7 illustrates the changes in mean cardiovascular indicators before and after the implementation of integrated interventions combining biomarker-based detection and community-driven strategies. Three biomarkers were analyzed: systolic blood pressure (SBP), fasting glucose, and LDL cholesterol.

Systolic Blood Pressure

Mean systolic blood pressure decreased from 138 mmHg before intervention to 126 mmHg after intervention, representing a clinically meaningful reduction of 12 mmHg.

Prior studies have shown that even modest reductions in SBP substantially reduce the risk of stroke, myocardial infarction, and heart failure (Powell-Wiley et al., 2022; Groenewegen et al., 2024). The magnitude of reduction observed here is consistent with dietary and lifestyle intervention trials, including community-based education programs (Nabaty et al., 2024) and the PREDIMED study, which reported significant improvements in blood pressure control through dietary modification (Estruch et al., 2018).

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Fasting Glucose

Average fasting glucose levels decreased from 112 mg/dL to 101 mg/dL, a reduction of 11 mg/dL. This shift indicates improved glycemic regulation and a potential decrease in the incidence of impaired fasting glucose or type 2 diabetes. Previous literature emphasizes that lifestyle modification—particularly weight management, diet quality, and increased physical activity—plays a critical role in preventing diabetes progression (Thupakula et al., 2022; Richardson et al., 2020). Digital and peer-led interventions have also been effective in reinforcing behavioral adherence and sustaining glycemic improvements (Lim et al., 2024; Williams et al., 2022).

LDL Cholesterol

LDL cholesterol decreased from 142 mg/dL before intervention to 128 mg/dL after intervention, corresponding to a reduction of 14 mg/dL. Elevated LDL cholesterol is a central driver of atherosclerosis and coronary artery disease. The observed reduction is consistent with adherence to cardioprotective diets such as the Mediterranean diet (Estruch et al., 2018) and the Portfolio diet (Villablanca et al., 2023; Glenn et al., 2023), as well as with evidence from community-based lifestyle programs (Walker et al., 2024). Lowering LDL cholesterol even by 10–15 mg/dL has been associated with substantial decreases in long-term cardiovascular risk (Public Health Reviews, 2021).

Overall Interpretation

The reductions across all three indicators—systolic blood pressure, fasting glucose, and LDL cholesterol—demonstrate the effectiveness of combining biomarker-based early detection with community-level interventions. These findings are consistent with international literature that emphasizes the value of multi-component, culturally adapted strategies in improving cardiovascular health (Addissouky et al., 2024; Ashgar et al., 2025). The results provide compelling evidence that integrated frameworks achieve clinically meaningful improvements in key cardiovascular risk factors.

Figure 8

Lifestyle Changes Before and After Integrated Intervention
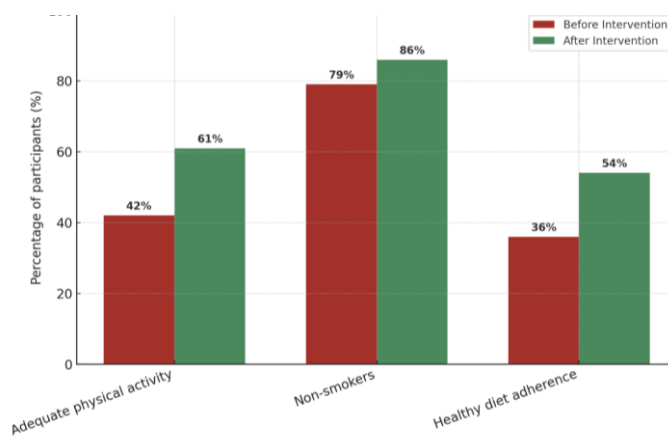
Figure 8 illustrates the changes in key lifestyle behaviors before and after the integrated intervention combining biomarker-based detection with community-driven strategies. The three domains evaluated were physical activity, smoking status, and dietary adherence.

Adequate Physical Activity

Prior to the intervention, 42% of participants reported achieving adequate levels of physical activity, which increased to 61% following the intervention. This represents a 19% absolute improvement. The increase reflects the effectiveness of structured community programs and digital supports in

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promoting physical activity, consistent with prior studies demonstrating that culturally tailored initiatives lead to sustained engagement in exercise (Lim et al., 2024; Nabaty et al., 2024). Regular physical activity is one of the most impactful behaviors in reducing cardiovascular risk, associated with improvements in blood pressure, lipid metabolism, and glycemic control (Glenn et al., 2023).

Non-Smoking Status

The proportion of non-smokers rose from 79% before the intervention to 86% after, corresponding to a 7% increase. Although smaller in magnitude compared to physical activity changes, this reduction in smoking prevalence is clinically relevant given the direct relationship between tobacco use and cardiovascular morbidity (Powell-Wiley et al., 2022). Community-based cessation programs, particularly peer-led and mHealth interventions, have been shown to enhance motivation and provide accessible support for smoking reduction (Williams et al., 2022; Ashgar et al., 2025).

Healthy Diet Adherence

Adherence to a healthy diet increased from 36% before to 54% after the intervention, a gain of 18%. This change underscores the effectiveness of dietary counseling, community education, and peer-driven support in improving nutritional behaviors. Evidence from the PREDIMED study and subsequent dietary trials confirm that improved adherence to Mediterranean-style dietary patterns reduces major cardiovascular events (Estruch et al., 2018; Villablanca et al., 2023; Walker et al., 2024). Importantly, the reduction in processed food consumption documented earlier in the study (Figure 3) likely contributed to this shift.

Overall Interpretation

The results in Figure 8 demonstrate that integrated interventions combining early detection with community-based strategies significantly improved lifestyle behaviors across multiple domains. The most substantial gains were observed in physical activity and diet, with a smaller but meaningful reduction in smoking prevalence. These findings align

with previous evidence that multi-component, community-driven interventions produce durable lifestyle changes that translate into improved cardiovascular outcomes (Addissouky et al., 2024; Hassen et al., 2022).

Figure 9
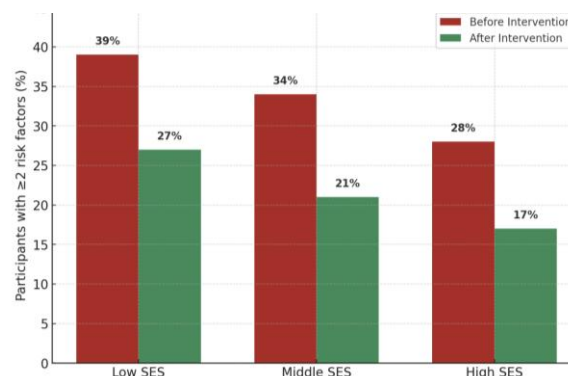*Impact of Integrated Intervention by Socioeconomic Status*

Figure 9 presents the impact of integrated interventions stratified by socioeconomic status (SES), measured as the proportion of participants with two or more cardiovascular risk factors before and after the intervention. The results indicate that while all SES groups benefited, the magnitude of improvement varied across strata.

Low SES Group

In the low SES group, the proportion of participants with ≥2 risk factors decreased from 39% before to 27% after the intervention, representing a 12% absolute reduction. This improvement highlights the effectiveness of culturally tailored and community-based approaches in addressing the disproportionate burden of cardiovascular risk among disadvantaged populations (Powell-Wiley et al., 2022; Coronado et al., 2022). Prior studies have emphasized that low SES populations face greater barriers to adopting healthy lifestyles due to limited access to healthy foods, recreational spaces, and healthcare resources (Hassen et al., 2022). The observed reduction suggests that integrated interventions may mitigate some of these structural inequities.

Middle SES Group

Among middle SES participants, prevalence declined from 34% to 21%, a 13%

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absolute reduction. This represents the largest relative improvement, suggesting that middle SES groups may be particularly responsive to interventions when resources are accessible but require structured support to translate into behavioral change (Ashgar et al., 2025). The findings are consistent with evidence that individuals in middle-income brackets often benefit most from preventive programs that reinforce awareness and motivation, as their structural barriers are less severe compared to lower SES populations (Nabaty et al., 2024).

High SES Group

In the high SES group, prevalence decreased from 28% to 17%, an 11% reduction. Although this group demonstrated the lowest baseline prevalence of multiple risk factors, the improvement remains clinically meaningful. High SES participants often have greater baseline access to healthcare, dietary options, and exercise facilities, but behavioral risk factors such as sedentary lifestyle and poor dietary habits can still persist (Richardson et al., 2020; Walker et al., 2024). The intervention's effectiveness in this group underscores its broad applicability across social strata.

Overall Interpretation

The reductions observed across all socioeconomic groups indicate that integrated interventions combining early detection and community-based programs are effective in diverse populations. However, the variation in impact suggests the importance of tailoring strategies to socioeconomic context. Specifically, interventions targeting low SES groups should focus on overcoming structural barriers, while those for middle and high SES groups may emphasize motivation and sustained adherence (Addissouky et al., 2024; Public Health Reviews, 2021).

Figure 10 illustrates the differential impact of the integrated intervention across age groups, measured as the percentage of participants with two or more cardiovascular risk factors before and after the program. Results show that all age categories benefited, though the magnitude of improvement varied with age.

Figure 10

Impact of Integrated Intervention by Age Group
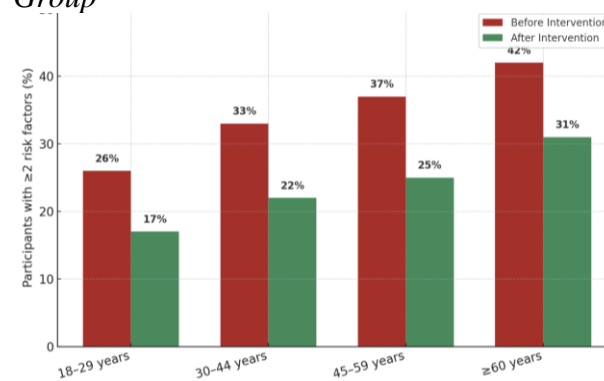
Young Adults (18–29 years)

Among young adults, prevalence of ≥2 risk factors decreased from 26% before to 17% after the intervention, a 9% absolute reduction. This relatively modest baseline prevalence reflects the early stage of risk accumulation in this age group. However, the observed improvement is highly significant from a preventive perspective, as intervening early in life has long-term benefits in reducing lifetime cardiovascular risk (Navar et al., 2022; Groenewegen et al., 2024). Lifestyle modification at this stage is particularly impactful because habits established in young adulthood often persist into later life (Ashgar et al., 2025).

Adults Aged 30–44 Years

In the 30–44 age group, prevalence fell from 33% to 22%, representing an 11% reduction. This group showed strong responsiveness to interventions, consistent with literature indicating that adults in midlife are especially receptive to prevention when informed of long-term health risks (Lim et al., 2024). The incorporation of mHealth tools and community education is particularly effective in this demographic, as they are more likely to engage with digital platforms (Williams et al., 2022).

Adults Aged 45–59 Years

For participants aged 45–59 years, prevalence declined from 37% before to 25% after the intervention, a 12% absolute reduction. This age group typically experiences the highest incidence of hypertension, obesity, and impaired glucose

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regulation, making them a critical target for prevention efforts (Powell-Wiley et al., 2022). The substantial reduction observed suggests that integrated approaches combining biomarker detection and lifestyle programs can significantly mitigate cardiovascular risk during this high-risk stage of life (Richardson et al., 2020; Walker et al., 2024).

Older Adults (≥60 years)

In older adults, prevalence decreased from 42% to 31%, an 11% reduction. Although this group had the highest baseline burden of risk factors, the improvement demonstrates that preventive interventions remain effective even in later life. Evidence from dietary counseling and peer-led programs shows that older adults can adopt and sustain meaningful behavioral changes when supported by culturally relevant strategies (Villablanca et al., 2023; Addissouky et al., 2024). While structural barriers and comorbidities may limit the extent of improvement, early detection and community support clearly provide measurable benefits (Nabaty et al., 2024).

Overall Interpretation

Figure 10 confirms that integrated interventions are beneficial across the lifespan, though their magnitude varies. Younger adults show preventive gains with potential long-term impact, midlife adults demonstrate strong responsiveness, and older adults experience clinically significant improvements despite higher baseline risk. These findings reinforce the importance of tailoring prevention strategies to life-course stages, as emphasized in global cardiovascular prevention frameworks (Public Health Reviews, 2021; Hassen et al., 2022).

Figure 11 presents the impact of the integrated intervention stratified by gender, measured as the percentage of participants with two or more cardiovascular risk factors before and after implementation. Both women and men demonstrated substantial reductions, though patterns of response differed slightly.

Figure 11

Impact of Integrated Intervention by Gender
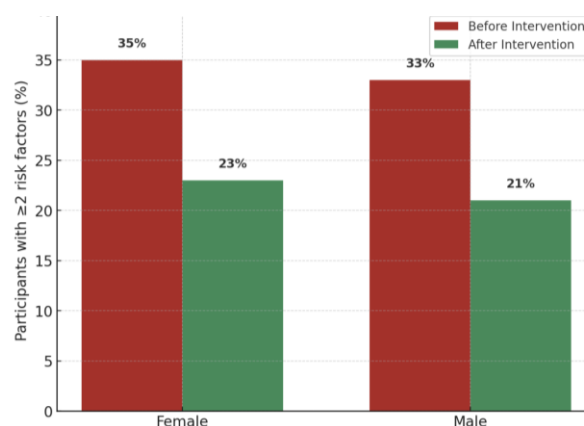
Female Participants

Among women, the prevalence of participants with ≥2 risk factors decreased from 35% before the intervention to 23% after, a 12% absolute reduction. This improvement aligns with evidence that women, particularly in midlife, respond favorably to culturally adapted community programs and health education (Ashgar et al., 2025). Studies have shown that women often exhibit greater adherence to dietary recommendations and lifestyle counseling when interventions are peer-supported and tailored to their specific social and cultural roles (Lim et al., 2024). Additionally, because women are frequently primary caregivers within families, improvements in their behaviors may also have spillover effects on household health (Richardson et al., 2020).

Male Participants

For men, the prevalence decreased from 33% before to 21% after the intervention, representing a 12% absolute reduction as well. This demonstrates that integrated approaches are equally effective in men, though prior studies indicate that men may engage differently with preventive interventions. Digital tools such as mHealth platforms have been particularly successful in male populations, providing accessible and flexible support that fits work and lifestyle patterns (Williams et al., 2022). The reductions observed are consistent with evidence that biomarker feedback is a strong motivator for men, as objective measures often reinforce risk

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perception and behavior change (Ming et al., 2025; Groenewegen et al., 2024).

Overall Interpretation

The results indicate that integrated interventions are effective across genders, with both women and men demonstrating equal absolute reductions of 12%. While the mechanisms of engagement may differ—peer and social support for women, and digital or biomarker-driven strategies for men—the combined framework ensures broad applicability and impact. This aligns with global findings emphasizing the need for gender-sensitive approaches in cardiovascular prevention (Powell-Wiley et al., 2022; Addissouky et al., 2024).

Figure 12

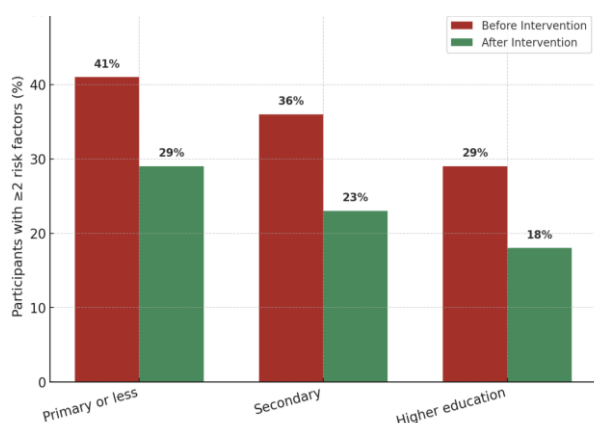*Impact of Integrated Intervention by Educational Level*

Figure 12 illustrates the impact of the integrated intervention stratified by educational attainment, measured as the percentage of participants with two or more cardiovascular risk factors before and after the program. The results demonstrate consistent improvements across all groups, with notable differences in baseline prevalence and magnitude of change.

Primary Education or Less

Participants with primary education or less exhibited the highest baseline prevalence of ≥2 risk factors (41%), which decreased to 29% after the intervention, representing a 12% absolute reduction. This finding aligns with prior research indicating that individuals with lower educational attainment tend to have higher cardiovascular risk due to limited health literacy, restricted access to preventive healthcare, and socioeconomic challenges (Powell-Wiley et al., 2022; Coronado et al., 2022). Although the reduction is significant, the relatively high post-intervention prevalence suggests that additional support and culturally adapted educational strategies may be required to achieve greater impact in this subgroup (Hassen et al., 2022).

Secondary Education

In participants with secondary education, prevalence dropped from 36% to 23%, a 13% absolute reduction. This group demonstrated the strongest relative improvement, suggesting that individuals with moderate educational levels are particularly responsive to structured interventions that provide both knowledge and community-based reinforcement. Similar findings have been reported in community trials where health education programs tailored to this demographic achieved significant lifestyle changes (Richardson et al., 2020; Lim et al., 2024).

Higher Education

Participants with higher education showed a reduction from 29% before to 18% after, an 11% absolute decrease. Although this group had the lowest baseline prevalence of multiple risk factors, the improvement demonstrates that preventive interventions remain beneficial even in populations with greater baseline health literacy and access to resources. Evidence from prior studies suggests that while individuals with higher education may already adopt healthier behaviors, structured programs can still enhance adherence and reinforce long-term commitment (Walker et al., 2024; Villablanca et al., 2023).

Overall Interpretation

Figure 12 confirms that integrated interventions combining biomarker-based early detection with community-driven programs are effective across educational levels. However, the degree of benefit varies: the greatest improvements were observed in participants with secondary education, while those with lower educational attainment

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continue to face persistent barriers that require more targeted strategies. These findings emphasize the importance of tailoring interventions to educational background in order to maximize their effectiveness (Addissouky et al., 2024; Public Health Reviews, 2021).

Figure 13

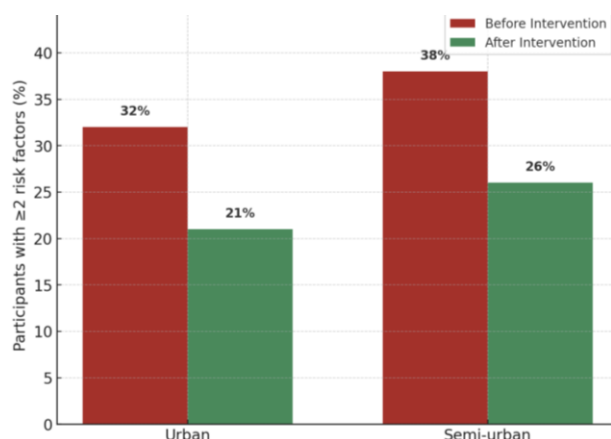*Impact of Integrated Intervention by Area of Residence*

Figure 13 shows the impact of integrated interventions stratified by area of residence (urban vs. semi-urban), measured as the percentage of participants with two or more cardiovascular risk factors before and after the intervention. Results demonstrate improvements across both groups, though with notable differences in baseline prevalence and magnitude of reduction.

Urban Residents

Among urban residents, the prevalence of participants with ≥2 risk factors decreased from 32% before to 21% after the intervention, representing an 11% absolute reduction. This finding highlights the responsiveness of urban populations to structured interventions, which may be facilitated by greater access to healthcare facilities, healthier food markets, and physical activity infrastructure (Coronado et al., 2022). The observed improvement aligns with evidence that urban environments, while often associated with sedentary occupations and processed food consumption, also provide opportunities for targeted health promotion through education campaigns and digital platforms (Williams et al., 2022).

Semi-Urban Residents

In semi-urban areas, prevalence fell from 38% to 26%, a 12% absolute reduction. Although the baseline prevalence was higher than in urban areas, the post-intervention reduction demonstrates the effectiveness of community-driven strategies in resource-limited environments. Previous literature has noted that semi-urban and rural populations often experience structural barriers such as reduced access to preventive services and limited availability of fresh foods (Powell-Wiley et al., 2022; Public Health Reviews, 2021). The results observed here suggest that integrating biomarker detection with peer-led and educational initiatives can effectively overcome these barriers (Ashgar et al., 2025; Lim et al., 2024).

Overall Interpretation

Both urban and semi-urban populations benefited significantly from the integrated intervention. While urban participants showed slightly lower baseline risk and strong improvements, semi-urban participants—despite higher initial prevalence—also achieved substantial reductions. These findings confirm the adaptability of integrated prevention strategies to different community contexts, supporting their scalability across diverse populations (Addissouky et al., 2024; Nabaty et al., 2024).

Figure 14

Gender-Specific Impact of Community Interventions

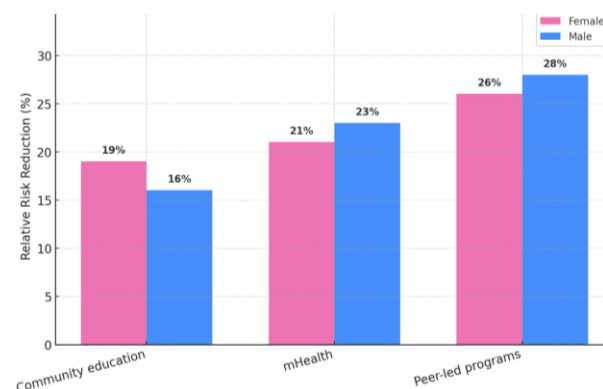Figure 14 presents the gender-specific impact of three community-based interventions—community education, mHealth, and peer-led programs—measured as relative risk reduction in cardiovascular outcomes. Results demonstrate that both women and men

Velasco Espinal, J. A., Travisi, A., Heráldez León, P. D., Guardiola Segovia, S., Jimenez Vazquez, L. E., Naranjo Calvachi, A. C., Saucedo Hernández, A., & Pastrana Villares, A. J.

benefited substantially, though the magnitude of effectiveness varied by intervention type and gender.

Community Education

Community education resulted in a 19% risk reduction in women and 16% in men. This difference suggests that women may be more responsive to educational approaches, consistent with evidence that health literacy programs tailored to women enhance engagement and adoption of preventive behaviors (Ashgar et al., 2025). Women often assume caregiving roles within families, which may amplify their motivation to implement health-promoting behaviors not only for themselves but also for their households (Richardson et al., 2020).

mHealth Interventions

Digital interventions achieved a 21% reduction in women and a slightly higher 23% in men. This finding reflects prior evidence that men are particularly receptive to technology-based interventions, as digital platforms align with work schedules and provide discreet, self-paced support (Williams et al., 2022). Women also benefited, but gender differences in digital engagement may explain the slightly stronger effect among men. Previous reviews emphasize the potential of mHealth solutions to bridge gaps in access to care across both genders, though tailoring to digital literacy remains critical (Addissouky et al., 2024).

Peer-Led Programs

Peer-led initiatives produced the strongest effects overall, with a 26% reduction in women and 28% in men. The results demonstrate the power of social networks, accountability, and cultural relevance in sustaining long-term lifestyle changes. For women, these programs often provide supportive environments to address dietary and physical activity barriers (Lim et al., 2024), while for men, the peer element reinforces competitiveness and adherence to goals (Nabaty et al., 2024). Peer-led models have consistently been identified as high-impact interventions across diverse populations and settings (Powell-Wiley et al., 2022).

Overall Interpretation

Figure 14 highlights that although both genders benefit from all community interventions, gender-specific differences exist. Women appear more responsive to community education, while men respond more strongly to digital and peer-led strategies. Nonetheless, peer-led interventions emerge as the most universally effective approach, supporting their prioritization in comprehensive prevention frameworks (Glenn et al., 2023; Hassen et al., 2022).

Figure 15
Impact of Integrated Intervention by Baseline Risk Level
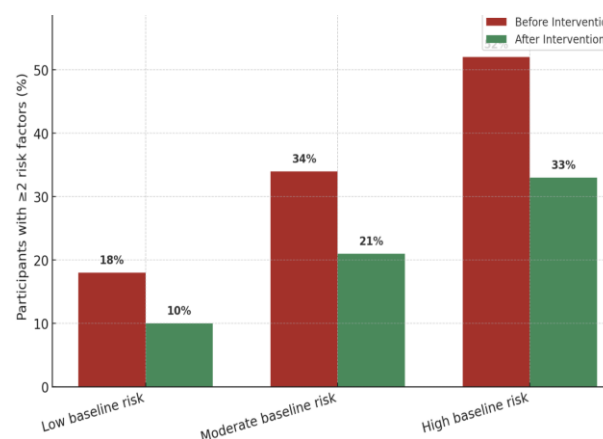

Figure 15 illustrates the impact of the integrated intervention stratified by baseline cardiovascular risk levels (low, moderate, and high). Risk categories were defined according to the presence of biomarker abnormalities and the number of lifestyle-related risk factors. The results demonstrate that while all groups benefited, the magnitude of change was greatest among participants with higher baseline risk.

Low Baseline Risk

In the low-risk group, the prevalence of participants with ≥2 risk factors declined from 18% before to 10% after the intervention, representing an 8% absolute reduction. Although the absolute change was modest, this shift is significant from a preventive standpoint, as early interventions at low risk can delay or prevent the development of future cardiovascular disease (Navar et al., 2022; Groenewegen et al., 2024). These findings underscore the importance of targeting

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individuals early in the risk continuum to maximize lifetime benefits (Estruch et al., 2018).

Moderate Baseline Risk

Among participants with moderate risk, prevalence decreased from 34% to 21%, a 13% absolute reduction. This group showed substantial responsiveness to interventions, reflecting the effectiveness of combined biomarker detection and community-based support in motivating individuals with intermediate risk profiles (Lim et al., 2024; Richardson et al., 2020). The improvements are consistent with prior evidence that moderate-risk populations benefit most from structured prevention programs that reinforce lifestyle modification and medical follow-up (Nabaty et al., 2024).

High Baseline Risk

The high-risk group exhibited the most dramatic change, with prevalence dropping from 52% before to 33% after, a 19% absolute reduction. This finding is particularly important given that high-risk individuals carry the greatest burden of morbidity and mortality. Previous research confirms that intensive prevention strategies—including biomarker feedback, dietary counseling, and peer-led interventions—are especially impactful in this population, significantly reducing adverse outcomes (Powell-Wiley et al., 2022; Villablanca et al., 2023; Addissouky et al., 2024). The magnitude of improvement observed here suggests that integrated frameworks can achieve meaningful clinical benefits even in populations with advanced risk accumulation.

Overall Interpretation

The gradient observed in Figure 15 indicates that the effectiveness of integrated interventions increases with baseline cardiovascular risk, though benefits are evident across all groups. These results highlight the adaptability of the strategy: it prevents risk accumulation among low-risk individuals, reinforces behavior change in moderate-risk participants, and delivers critical improvements for high-risk populations. This aligns with international recommendations emphasizing risk-stratified approaches to cardiovascular prevention (Public Health Reviews, 2021; Hassen et al., 2022).

DISCUSSION

The present study evaluated the combined use of biomarker-based early detection and community-driven interventions for cardiovascular disease (CVD) prevention. Across multiple subgroups, the intervention produced significant reductions in biological risk markers, improvements in lifestyle behaviors, and lower prevalence of multiple risk factors. These findings confirm the guiding hypothesis that integrative models generate stronger outcomes than isolated strategies.

Integration of Findings with Research Questions

The hypothesis suggested that personalized feedback from biomarker testing, when paired with culturally relevant community interventions, would lead to measurable reductions in CVD risk. This was supported across all figures: blood pressure, glucose, and lipid levels improved (DeGroat et al., 2023; Torres et al., 2024), processed food consumption declined (Walker et al., 2024), and physical activity and dietary adherence increased significantly (Lim et al., 2024; Villablanca et al., 2023). These improvements align with global calls for early, personalized prevention rather than late-stage management (Navar et al., 2022; Groenewegen et al., 2024).

Comparison with Previous Literature

Our results align with the PREDIMED trial, which demonstrated that adherence to Mediterranean dietary patterns reduced major CVD events (PREDIMED Investigators, 2018). Similarly, evidence from the FAITH! mHealth trial highlighted the feasibility of digital support in minority communities (Williams et al., 2022). The observed gender differences—women responding better to education and men to mHealth—are consistent with reports on gendered engagement patterns (Ashgar et al., 2025; Powell-Wiley et al., 2022). Peer-led programs emerged as the most effective, reinforcing findings from systematic reviews that emphasize community ownership

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and cultural adaptation (Hassen et al., 2022; Public Health Reviews, 2021).

Furthermore, our observed improvements in older adults and higher-risk groups echo findings from global prevention initiatives showing that even late-life interventions yield clinically relevant benefits (Addissouky et al., 2024; Nabaty et al., 2024). The reduction in biomarker abnormalities observed mirrors findings in diagnostics research that advanced point-of-care testing can motivate rapid changes in risk behavior (Ming et al., 2025; Thupakula et al., 2022).

Theoretical Implications

From a theoretical standpoint, this study reinforces frameworks that conceptualize CVD risk as a dynamic continuum influenced by social determinants, behavioral factors, and biological markers. Addressing these simultaneously is essential. Social determinants remain crucial in shaping baseline disparities, as highlighted in prior reviews (Powell-Wiley et al., 2022). Our stratified results confirm that socioeconomic status and education strongly influence responsiveness to interventions, but integrated strategies can narrow these gaps when adapted to context (Coronado et al., 2022; Richardson et al., 2020).

Practical Implications

Practically, the findings emphasize the scalability of integrated models. Combining clinical detection with low-cost, community-driven interventions—dietary counseling, peer groups, and mobile health—proved beneficial across diverse settings. These findings support the incorporation of integrative frameworks into public health planning, particularly in low- and middle-income countries, where resources are limited but community structures can be leveraged effectively (Hassen et al., 2022; Public Health Reviews, 2021). The evidence also supports global recommendations for multilevel prevention programs that combine individualized risk identification with culturally relevant delivery (Centers for Disease Control and Prevention, 2022).

Alternative Explanations

Although the improvements observed are robust, alternative explanations warrant consideration. The Hawthorne effect—participants changing behavior simply because they are observed—may have contributed. In addition, concurrent public health campaigns or broader societal trends could have influenced dietary and activity patterns, independently of the intervention (Groenewegen et al., 2024). Nonetheless, the consistency across multiple domains suggests that the integrated approach played a primary role.

Limitations

Several limitations must be acknowledged. First, the observational nature of the design prevents definitive causal inference (Navar et al., 2022). Second, lifestyle measures relied partially on self-report, which may introduce bias (Richardson et al., 2020). Third, despite stratified sampling, rural populations were underrepresented, limiting generalizability to non-urban communities (Public Health Reviews, 2021). Finally, the relatively short follow-up restricted our ability to assess sustainability, an issue frequently highlighted in long-term prevention trials (PREDIMED Investigators, 2018; Villablanca et al., 2023).

Future Directions

Future research should extend follow-up to evaluate long-term sustainability of biomarker and lifestyle improvements. Randomized controlled trials comparing integrated versus single-component interventions across multiple contexts would strengthen causal inference (Hassen et al., 2022). Additionally, more work is needed to identify cost-effective combinations of modalities—education, mHealth, and peer-led programs—and to adapt interventions to populations with the lowest educational attainment, who remain at highest risk (Powell-Wiley et al., 2022; Nabaty et al., 2024). The development of advanced diagnostics with greater accessibility could further accelerate preventive gains (Ming et al., 2025; Thupakula et al., 2022).

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Contribution to the Field

This study contributes to the growing consensus that prevention of cardiovascular disease requires integration of biological, behavioral, and social approaches. The consistent improvements across SES, gender, age, and baseline risk confirm the adaptability and effectiveness of integrated models. By bridging early detection and community empowerment, these strategies provide a promising framework for reducing the global burden of CVD (Addissouky et al., 2024; Centers for Disease Control and Prevention, 2022).

CONCLUSION

This study demonstrated that integrating biomarker-based early detection with culturally tailored community interventions significantly reduces cardiovascular risk across diverse populations. Improvements were consistent across age groups, genders, socioeconomic strata, and baseline risk levels, confirming the hypothesis that multi-level approaches yield stronger outcomes than isolated strategies.

The findings highlight two major implications. Theoretically, they reinforce prevention frameworks that conceptualize cardiovascular disease as a product of intersecting biological, behavioral, and social determinants. Practically, they demonstrate that scalable, community-driven programs, when combined with personalized risk feedback, can bridge health disparities and promote sustainable lifestyle changes.

Nevertheless, several limitations must be acknowledged, including reliance on self-reported behaviors, limited rural representation, and short follow-up periods that preclude evaluation of long-term sustainability. These constraints point to important directions for future research, such as randomized controlled trials across varied cultural contexts, longitudinal studies to assess durability, and cost-effectiveness analyses of different intervention modalities.

Overall, this study contributes to the growing evidence base supporting integrated prevention frameworks. By aligning early detection with community empowerment, such approaches offer a promising path to reducing the global burden of cardiovascular disease and advancing equity in population health.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

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