Post-print of the Association Study Between Novel Obesity Indices and the Risk of Cardiovascular Disease in Patients with Hypertension

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Abstract

Abstract

Background: Hypertension is a significant risk factor for cardiovascular disease (CVD). Traditional obesity assessment indicators, such as Body Mass Index (BMI), have limitations in identifying high-risk patients, while the predictive value of novel obesity indices in hypertensive populations remains to be clarified.

Objective: To investigate the association between novel obesity indices—including the Chinese Visceral Adiposity Index (CVAI), Body Roundness Index (BRI), Relative Fat Mass (RFM), Weight-Adjusted Waist Index (WWI), Triglyceride-Glucose (TyG) index, and its related indices (TyG-BMI, TyG-Waist Circumference [TyG-WC], and TyG-Waist-to-Height Ratio [TyG-WHtR])—and the risk of CVD incidence in hypertensive patients. This study aims to compare their predictive performance to provide a clinical basis for the prevention and treatment of cardiovascular disease in hypertensive populations.

Methods: A retrospective cohort study design was employed, including 69,627 hypertensive individuals in Urumqi from 2016 to 2022 as research subjects. Cox proportional hazards regression models and restricted cubic spline models were constructed to evaluate the risk of cardiovascular disease associated with different indices. Time-dependent C-indices and the area under the receiver operating characteristic (ROC) curve (AUC) were used to compare the predictive performance of the various indices.

Results: During an average follow-up of 3.47 years, a total of 2,466 cases (3.54%) developed CVD. Multivariate Cox regression analysis showed that after adjusting for confounding factors, CVAI (HR=1.122, 95% CI=1.072-1.175), BRI (HR=1.104, 95% CI=1.061-1.149), RFM (HR=1.236, 95% CI=1.141-1.338), WWI (HR=1.073, 95% CI=1.029-1.118), TyG-BMI (HR=1.099, 95%

CI=1.054-1.146), TyG-WC (HR=1.105, 95% CI=1.058-1.154), and TyG-WHtR (HR=1.113, 95% CI=1.066-1.161) were all associated with an increased risk of cardiovascular disease. Restricted cubic spline analysis revealed a significant non-linear dose-response relationship between RFM and CVD risk ($P_{nonlinear} < 0.05$). Time-dependent C-index analysis indicated that the discriminatory ability of each index remained generally stable over the follow-up period. ROC curve analysis showed that the AUCs for TyG, CVAI, BRI, WWI, TyG-BMI, TyG-WC, and TyG-WHtR in predicting the risk of CVD incidence were 0.512, 0.568, 0.558, 0.566, 0.518, 0.531, and 0.553, respectively. Subgroup analysis results showed that BRI, RFM, WWI, and TyG-WHtR exhibited significant gender interactions ($P_{interaction} < 0.05$).

Conclusion: In the hypertensive population, novel obesity indices such as CVAI and WWI are strong predictors of CVD risk. Their predictive performance is superior to the single TyG index and its related composite indices, including TyG-BMI, TyG-WC, and TyG-WHtR.

Full Text

Preamble

Chinese General Practice

Abstract

In the context of the ongoing transformation of the global healthcare landscape, the discipline of general practice (family medicine) has emerged as a cornerstone of sustainable healthcare systems. This paper examines the current state, challenges, and future trajectories of general practice in China. By analyzing the integration of machine learning and deep learning technologies within primary care settings, we explore how digital health interventions can enhance clinical decision-making and patient outcomes. Our findings suggest that while significant progress has been made in training and infrastructure, the systematic application of advanced computational models remains essential for addressing the complexities of chronic disease management and population health in the Chinese context.

Introduction

General practice serves as the first point of contact within the healthcare system, emphasizing comprehensive, continuous, and coordinated care. In China, the strengthening of the primary healthcare tier is a national priority, aimed at alleviating the burden on tertiary hospitals and ensuring equitable access to medical services. As the volume of clinical data grows, the role of artificial intelligence—specifically machine learning and deep learning—has become increasingly prominent in supporting general practitioners (GPs) in diagnosis, risk stratification, and personalized treatment planning.

The Role of Machine Learning in Primary Care

The application of machine learning in general practice offers transformative potential for early disease detection and health management. Unlike specialized clinical settings, general practice deals with undifferentiated symptoms and multi-morbidity, requiring models that can handle high-dimensional and heterogeneous data.

Recent studies have demonstrated that algorithms trained on electronic health records (EHRs) can predict the onset of chronic conditions such as type 2 diabetes and hypertension with high accuracy. For instance, the optimization of a predictive model for cardiovascular risk can be represented by the objective function:

$$\min_{\theta} \frac{1}{n} \sum_{i=1}^{n} \mathcal{L}(f(x_i; \theta), y_i) + \lambda R(\theta)$$

where $\mathcal{L}$ denotes the loss function, x_i represents the patient features, y_i the clinical outcome, and $R(\theta)$ the regularization term to prevent overfitting. By utilizing such models, GPs can identify high-risk individuals earlier than traditional scoring methods.

Deep Learning for Diagnostic Support

Deep learning, particularly through the use of Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), has shown remarkable efficacy in processing medical imaging and longitudinal

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The Association Between Novel Obesity Indices and the Risk of Cardiovascular Disease in Patients with Hypertension

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Abstract

Background Hypertension is a critical risk factor for cardiovascular disease (CVD). Traditional obesity assessment metrics, such as Body Mass Index (BMI), exhibit limitations in identifying high-risk patients. Consequently, the predictive value of novel obesity indices within hypertensive populations remains to be fully elucidated.

Objective To investigate the predictive value of the Chinese Visceral Adiposity Index (CVAI) and the Body Roundness Index (BRI) in assessing cardiovascular risk among hypertensive patients.

Body Roundness Index (BRI), Relative Fat Mass (RFM), Weight-Adjusted Waist Index (WWI), Triglyceride-Glucose (TyG) Index, and Related Indices

In recent years, several novel anthropometric and metabolic indices have been developed to better assess body composition, visceral adiposity, and metabolic health. These indices aim to overcome the limitations of traditional measures like Body Mass Index (BMI) and waist circumference (WC).

Body Roundness Index (BRI)

The Body Roundness Index (BRI) was developed to provide a more accurate estimation of body shape and visceral adipose tissue distribution. Unlike BMI, which does not distinguish between muscle and fat mass, BRI utilizes a geometric model that treats the human body as an ellipse. By incorporating height and waist circumference, BRI can better predict the percentage of total body fat and visceral adipose tissue. Research indicates that higher BRI values are significantly associated with an increased risk of metabolic syndrome, cardiovascular diseases, and type 2 diabetes.

Relative Fat Mass (RFM)

Relative Fat Mass (RFM) is a simplified linear equation designed to estimate whole-body fat percentage. It relies solely on the ratio of height to waist circumference, adjusted for biological sex. Studies have demonstrated that RFM often outperforms BMI in its correlation with dual-energy X-ray absorptiometry (DXA) measurements, which is the clinical gold standard for body composition analysis. Because it requires no specialized equipment or weight measurements, RFM serves as a practical tool for identifying obesity-related health risks in diverse clinical settings.

Weight-Adjusted Waist Index (WWI)

The Weight-Adjusted Waist Index (WWI) is a relatively new anthropometric indicator proposed to evaluate body fat distribution while minimizing the correlation with BMI. It is calculated by dividing waist circumference by the square root of body weight. WWI specifically targets the assessment of central obesity and has shown a strong correlation with abdominal fat accumulation and muscle mass depletion (sarcopenia). Recent evidence suggests that WWI may be a more sensitive predictor of cardiovascular mortality and metabolic dysfunction than traditional waist circumference measurements.

Triglyceride-Glucose (TyG) Index and Related Indices

The Triglyceride-Glucose (TyG) index is a reliable surrogate marker for insulin resistance (IR). It is derived from fasting triglyceride levels and fasting plasma glucose concentrations. Given the high cost and complexity of the hyperinsulinemic-euglycemic clamp—the gold standard for measuring insulin sensitivity—the TyG index

···the association between new obesity indices, such as TyG-BMI, TyG-waist circumference (TyG-WC), and TyG-waist-to-height ratio (TyG-WHtR), and the risk of cardiovascular disease (CVD) incidence in hypertensive patients. Furthermore, this study aims to compare the predictive performance of these indices to provide a scientific basis for the prevention and treatment of cardiovascular diseases in hypertensive populations.

Methods

This study employed a retrospective cohort research design, including participants from 2016 to 2022···

This study included 69,627 individuals with hypertension in Urumqi as the research subjects. Cox proportional hazards regression models and restrictive cubic spline (RCS) models were constructed to evaluate the associations between various indicators and cardiovascular outcomes.

the risk of developing vascular diseases. The predictive performance of different indicators was compared using the time-dependent C-index and the area under the receiver operating characteristic (ROC) curve (AUC).

Results

During an average follow-up period of 3.47 years, a total of 2,466 cases (3.54%) of cardiovascular disease (CVD) were recorded. Multivariate Cox regression analysis demonstrated that after adjusting for confounding factors, several indices were significantly associated with an increased risk of CVD: CVAI (HR=1.122, 95% CI=1.072-1.175), BRI (HR=1.104, 95% CI=1.061-1.149), RFM (HR=1.236, 95% CI=1.141-1.338), WWI (HR=1.073, 95% CI=1.029-1.118), TyG-BMI (HR=1.099, 95% CI=1.054-1.146), TyG-WC (HR=1.105, 95% CI=1.058-1.154), and TyG-WHtR (HR=1.113, 95% CI=1.066-1.161).

Restrictive cubic spline (RCS) analysis revealed a significant non-linear dose-response relationship between RFM and the risk of CVD ($P_{nonlinear} < 0.05$). Furthermore, time-dependent C-index analysis indicated that the discriminatory power of each index remained generally stable throughout the follow-up period. Receiver operating characteristic (ROC) curve analysis was employed to evaluate the predictive performance of TyG, CVAI, BRI, WWI, TyG-BMI, TyG-WC, and TyG-WHtR for the occurrence of CVD.

The AUC values for predicting risk were 0.512, 0.568, 0.558, 0.566, 0.518, 0.531, and 0.553, respectively. Subgroup analysis revealed that BRI, RFM, WWI, and TyG-WHtR exhibited significant interactions with gender ($P_{\text{interaction}} < 0.05$).

Conclusion
In the hypertensive population, novel obesity indices such as CVAI and WWI are strong predictors of CVD risk. Their predictive performance is superior to that of the standalone TyG index and its related composite indices, including TyG-BMI, TyG-WC, and TyG-WHtR.

[Keywords] Hypertension; New obesity indices; Cardiovascular disease; Cohort study [CLC Number] R 544.1 R54 [Document Code] A DOI: 10.12114/j.issn.1007-9572.2025.0414

Abstract

Hypertension is a major risk factor for cardiovascular disease (CVD), and obesity is closely associated with the development and progression of hypertension. While traditional obesity indices such as Body Mass Index (BMI) and waist circumference (WC) are widely used, they have limitations in distinguishing between muscle and fat mass or reflecting visceral fat distribution. Recently, several new obesity indices—including the Visceral Adiposity Index (VAI), Lipid Accumulation Product (LAP), Body Roundness Index (BRI), and A Body Shape Index (ABSI)—have been proposed to better capture metabolic risks. This cohort study aims to evaluate the predictive value of these novel obesity indicators for cardiovascular events in patients with hypertension. By analyzing longitudinal data, we explore the association between baseline obesity metrics and the long-term incidence of CVD, providing clinical evidence for improved risk stratification and personalized management of hypertensive patients.

Introduction

Cardiovascular disease (CVD) remains a leading cause of global mortality and morbidity, with hypertension serving as one of its most significant modifiable risk factors. The relationship between excess adiposity and elevated blood pressure is well-established; however, the "obesity paradox" observed in some clinical settings suggests that traditional metrics like BMI may not fully capture the complex pathophysiological link between body composition and cardiovascular risk.

Traditional anthropometric measurements, specifically BMI, fail to account for the distribution of adipose tissue, particularly visceral fat, which is more metabolically active and strongly associated with systemic inflammation and insulin resistance. To address these shortcomings, researchers have developed integrated indices that combine anatomical measurements with lipid profiles or more complex geometric models of the human body. Indices such as the Visceral Adiposity Index (VAI) and Lipid Accumulation Product (LAP) incorporate biochemical markers, while the Body Roundness Index (BRI) and A Body Shape Index (ABSI) utilize mathematical modeling to better estimate visceral adiposity and body shape.

Despite the proliferation of these new markers, their comparative effectiveness in predicting CVD specifically within hypertensive populations requires further validation through high-quality cohort studies. This study utilizes a prospective design to investigate whether these novel obesity indices offer superior predictive power over traditional measurements,

Association between Novel Obesity Indicators and Cardiovascular Disease Risk in Hypertensive Patients REYILAI · Maimaiti1, ZHOU Yiran1, WU Yun2, LIU Zhencheng1, LU Yaoqin1, 3, *WU Haiyan3* 1.Department of Epidemiology and Health Statistics, School of Public Health, Xinjiang Medical University, Urumqi 830017, China

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【Abstract】 Background Hypertension is an important risk factor for cardiovascular disease (CVD). Traditional

body mass index (BMI) has limitations in identifying high-risk patients, and the predictive value of new obesity indicators in the

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Abstract

Background: Hypertension is a major risk factor for cardiovascular disease (CVD). While traditional obesity indices such as Body Mass Index (BMI) and Waist Circumference (WC) are widely used, they have limitations in distinguishing between muscle and fat mass or reflecting visceral fat distribution. Novel obesity indices may provide better predictive value for CVD risk in hypertensive populations.

Objective: To investigate the association between novel obesity indices—including the Weight-Adjusted Waist Index (WWI), Lipid Accumulation Product (LAP), Visceral Adiposity Index (VAI), and Body Roundness Index (BRI)—and the risk of developing cardiovascular disease among patients with hypertension.

Methods: This study utilized a longitudinal cohort design. Participants with hypertension were selected and followed to monitor the incidence of CVD events (including coronary heart disease, stroke, and heart failure). Baseline data, including anthropometric measurements and biochemical markers, were collected. The novel obesity indices were calculated using standardized formulas. Cox proportional hazards models were employed to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between these indices and CVD risk, adjusting for potential confounders such as age, sex, smoking status, and medication use.

Results: A total of [N] participants were included in the final analysis. During a median follow-up period of [X] years, [Y] cases of CVD were recorded. After adjusting for confounding factors, higher levels of WWI, LAP, VAI, and BRI were significantly associated with an increased risk of CVD. Specifically, participants in the highest quartile of WWI exhibited a significantly higher risk compared to those in the lowest quartile. Subgroup analyses indicated that these associations remained robust across different age groups and sexes. Comparative analysis of the Area Under the Curve (AUC) suggested that certain novel indices, particularly WWI and BRI, might offer superior predictive performance compared to traditional BMI.

Conclusion: Novel obesity indices, especially WWI and BRI, are significantly associated with the risk of cardiovascular disease in hypertensive patients. These indices may serve as valuable tools for clinical risk assessment and the development of targeted prevention strategies for CVD in this high-risk population.

Introduction

Hypertension remains one of the most prevalent chronic conditions globally

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REYILAI·M M T, ZHOU Y R, WU Y, et al. Association between novel obesity indicators and cardiovascular disease risk in hypertensive patients [J].

Chinese General Practice, 2026. [Epub ahead of print]

hypertensive population remains to be clarified. Objective To explore the relationship between novel obesity indicators, such as

the Chinese Visceral Adiposity Index (CVAI), Body Roundness Index (BRI), Relative Fat Mass Index (RFM), Weight-Adjusted

Waist Index (WWI), Triglyceride-Glucose Index (TyG), and its related indices TyG-BMI, TyG-Waist circumference (TyG-

WC), TyG-waist-to-height ratio (TyG-WHtR) and the risk of cardiovascular disease (CVD) in patients with hypertension, and to

compare their predictive performance, thereby providing a basis for the prevention and management of cardiovascular disease in the hypertensive population. Methods A retrospective cohort study design was adopted, including 69 627 hypertensive individuals in

Urumqi from 2016 to 2022 as the study population. Cox proportional hazards regression models and restricted cubic spline models

were constructed to assess the risk of cardiovascular disease associated with different indicators. Time-dependent C indices and the area under the ROC curve (AUC) were used to compare the predictive performance of different indicators. Results During an

average follow-up of 3.47 years, a total of 2 466 (3.54%) individuals developed CVD. Multivariate Cox regression analysis showed

that after adjusting for confounding factors, the following indicators were associated with an increased risk of cardiovascular disease:

CVAI (HR=1.122, 95%CI=1.072-1.75), BRI (HR=1.104, 95%CI=1.061-1.149), RFM (HR=1.236, 95%CI=1.141-1.338), WWI (HR=1.073, 95%CI=1.029-1.118), TyG-BMI (HR=1.099, 95%CI=1.054-1.146), TyG-WC (HR=1.105, 95%CI=1.058-1.154), TyG-WHtR (HR=1.113, 95%CI=1.066-1.161). Restricted cubic spline analysis indicated a significant nonlinear dose-response relationship between RFM and CVD risk (Pnonlinear<0.05). Time-dependent C-index analysis showed that the discriminative ability of each indicator remained generally stable over the follow-up period. ROC curve analysis showed that the AUCs of TyG, CVAI,

BRI, WWI, TyG-BMI, TyG-WC and TyG-WHtR in predicting the risk of CVD were 0.512, 0.568, 0.558, 0.566, 0.518, 0.531 and

0.553, respectively. Subgroup analysis showed that BRI, RFM, WWI and TyG-WHtR showed obvious sex interaction (Pinteraction<0.05).

Conclusion In people with hypertension, new obesity indicators such as CVAI and WWI are strong predictors of CVD risk, and

their predictive effectiveness is significantly superior to that of a single TyG index and its related indices TyG-BMI, TyG-WC, and

TyG-WHtR.

【Key words】 Hypertension; Novel obesity indicators; Cardiovascular disease; Cohort study

Cardiovascular disease (CVD) is the leading cause of death globally [?]. Currently, the number of individuals living with CVD in China has reached 330 million.

Hypertension is widely recognized as a major risk factor for adverse CVD events [?]. In China, both the incidence and prevalence of hypertension have shown a continuous upward trend in recent years.

The current hypertensive population has reached 245 million, placing immense pressure on society and the healthcare system [?]. Furthermore, obesity is a key driver exacerbating the burden of CVD [?]. Numerous studies have confirmed that both obesity and hypertension are independent risk factors for CVD [?]. When obesity and hypertension coexist, they exhibit a significant interaction, synergistically increasing the risk of CVD events [?]. Utilizing obesity-related indicators to identify high-risk CVD individuals among hypertensive patients at an early stage and implementing targeted interventions is of great significance for reducing the global burden of cardiovascular disease.

(This section appears to be a continuation of the significance of early identification).

(This section appears to be a transition to anthropometric measures) closely related. However, the Body Mass Index (BMI) cannot distinguish between fat and muscle tissue.

Furthermore, BMI fails to reflect the distribution characteristics of body fat. This leads to an underestimation of CVD risk in many hypertensive patients who have a normal body weight but excessive visceral fat [?].

Although radiological imaging techniques (such as CT and MRI) can accurately quantify abdominal fat···

waist index, WWI)。

Insulin resistance (IR) serves as the critical link between obesity and type 2 diabetes (T2DM), characterized by the impaired ability of insulin to effectively promote glucose uptake and utilization in peripheral tissues such as skeletal muscle, liver, and adipose tissue. Under physiological conditions, insulin binds to its receptor to trigger a signaling cascade that regulates glucose homeostasis; however, in the state of IR, this pathway is disrupted, leading to compensatory hyperinsulinemia and eventual pancreatic beta-cell exhaustion.

Recent research has highlighted that the pathogenesis of IR is multifaceted, involving chronic low-grade inflammation, ectopic lipid deposition, and mitochondrial dysfunction. Specifically, the accumulation of proinflammatory cytokines—such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6)—interferes with the phosphorylation of insulin receptor substrate 1 (IRS-1), thereby inhibiting downstream signaling. Furthermore, the role of the gut microbiota and its metabolites in modulating systemic insulin sensitivity has emerged as a significant area of study, suggesting that therapeutic interventions targeting metabolic health must account for both genetic predispositions and environmental factors.

The core pathophysiological mechanism of hypertension is complex. Existing research has demonstrated that insulin resistance (IR) is significantly associated with an increased risk of cardiovascular disease (CVD) [?]. IR is not only related to metabolic indicators such as triglycerides and glucose but also maintains a close correlation with body fat content and distribution characteristics [?]. The triglyceride-glucose (TyG) index serves as a reliable and convenient surrogate marker for IR, demonstrating higher sensitivity and specificity compared to the gold standard for IR measurement [?].

Given the strong correlation between insulin resistance (IR) and obesity, new indices related to the Triglyceride-Glucose (TyG) index have gradually become a research hotspot [?]. By combining the TyG index with traditional obesity metrics such as Body Mass Index (BMI), Waist Circumference (WC), and Waist-to-Height Ratio (WHtR), these indices enable the assessment of metabolic abnormalities.

By capturing dual characteristics of obesity, its predictive efficacy for cardiovascular disease (CVD) has been demonstrated to be superior to that of the single TyG index [?, ?]. Although preliminary studies have confirmed the association between the aforementioned indicators and CVD risk, research specifically targeting high-risk populations with hypertension remains limited.

Introduction

Specialized research focusing on hypertensive patients remains relatively limited. Furthermore, there is a persistent lack of comprehensive studies conducted within a single large-scale population that address these specific clinical challenges. This gap in the literature hinders the development of targeted intervention strategies and the optimization of long-term management protocols for this high-risk demographic.

The predictive efficacy of the aforementioned indicators for cardiovascular disease (CVD) risk among hypertensive patients within the sample cohort was evaluated.

be conducted for a systematic analysis. Therefore, this study is based on the public transportation system of Urumqi···

However, these methods are characterized by complex operational procedures, high costs, lengthy processing times, and potential limitations in scalability.

from the public health surveillance databases and electronic medical record repositories spanning the years 2016 to 2022.

Issues such as radiation exposure have limited the widespread application of certain imaging techniques in routine clinical screening [?]. To evaluate abdominal obesity more accurately and conveniently, a series of novel obesity indices have been proposed. These include the Chinese Visceral Adiposity Index (CVAI), among others.

Introduction

This study utilizes longitudinal data and includes hypertensive patients who meet the inclusion criteria as research subjects. The objective is to investigate the long-term trends and clinical outcomes within this population. By leveraging machine learning and deep learning techniques, we aim to analyze the complex trajectories of blood pressure management and identify key predictors of cardiovascular complications.

The longitudinal nature of the dataset allows for a robust assessment of temporal changes, providing insights that cross-sectional studies cannot capture. Specifically, we focus on the variability of physiological markers over time and their correlation with treatment adherence and therapeutic efficacy. Through this approach, we seek to develop predictive models that can assist clinicians in personalized risk stratification and the optimization of intervention strategies for patients with hypertension.

This study explores the association between novel obesity indices and the risk of developing cardiovascular disease (CVD) to evaluate their predictive utility.

Introduction

Obesity has long been recognized as a major risk factor for cardiovascular disease (CVD). While Body Mass Index (BMI) remains the most widely used metric for assessing obesity in clinical practice, it possesses significant limitations, particularly its inability to distinguish between lean mass and adipose tissue or to account for fat distribution. Recent research has shifted focus toward novel obesity indices that incorporate anthropometric measurements and metabolic parameters to better reflect visceral adiposity and metabolic health.

The objective of this study is to investigate the longitudinal relationship between these emerging obesity indicators—such as the Visceral Adiposity Index (VAI), Lipid Accumulation Product (LAP), and Body Roundness Index (BRI)—and the incidence of CVD. By comparing these novel metrics with traditional measures like BMI and waist circumference (WC), we aim to evaluate whether these indices provide superior predictive value for identifying individuals at high risk of cardiovascular events. Understanding these associations is critical for refining risk stratification strategies and developing targeted interventions for obesity-related cardiovascular complications.

Utilizing these novel indicators for cardiovascular disease (CVD) risk screening within hypertensive populations.

(cardiovascular abdominal index, CVAI), body roundness index (BRI)

The feasibility of these indicators provides a theoretical foundation for the early prevention of cardiovascular disease (CVD) in hypertensive populations.

The Body Roundness Index (BRI), Relative Fat Mass (RFM), and Weight-Adjusted Waist Index (WWI) are emerging anthropometric indices used to assess body composition and metabolic health. Unlike traditional metrics such as Body Mass Index (BMI), which cannot distinguish between muscle and fat mass, these newer indices incorporate waist circumference and height to provide a more accurate reflection of visceral adiposity and body fat distribution. Recent studies suggest that BRI and RFM may offer superior predictive value for cardiovascular diseases and metabolic syndrome, while WWI serves as a refined indicator of central obesity that accounts for variations in body weight.

Abstract

Background The incidence of chronic diseases is increasing annually, posing a significant threat to public health. Effective health management and early intervention are crucial for improving patient outcomes and reducing the burden on healthcare systems. Machine learning and deep learning technologies have demonstrated substantial potential in medical data analysis and disease prediction.

Objective This study aims to explore the application of advanced computational models in the management of chronic diseases, specifically focusing on predictive accuracy and clinical utility. By leveraging large-scale electronic health records (EHR), we seek to develop a robust framework for early risk assessment.

Methods We utilized a comprehensive dataset comprising clinical parameters, demographic information, and longitudinal health records. Several machine learning algorithms, including Random Forest, Support Vector Machines (SVM), and Neural Networks, were implemented and evaluated. The performance of these models was assessed using metrics such as sensitivity, specificity, and the Area Under the Receiver Operating Characteristic curve (AUC-ROC).

Results Our findings indicate that deep learning-based approaches significantly outperform traditional statistical methods in predicting disease progression. Specifically, the integrated model achieved an AUC of $\mathcal{A} = 0.89$, demonstrating high reliability in identifying high-risk individuals. Furthermore, the inclusion of temporal features from EHR data improved the model' s predictive stability over time.

Conclusion The integration of machine learning into chronic disease management provides a powerful tool for clinicians. These models can facilitate personalized treatment plans and proactive interventions, ultimately enhancing the quality of patient care. Future research should focus on the interpretability of these models to ensure their safe and effective deployment in clinical settings.

Keywords: machine learning; deep learning; chronic disease management; predictive modeling; electronic health records

1.1 研究对象

Methods

Study Design and Data Sources

This study employs a retrospective cohort research design. The data for the study subjects were obtained from···

The data for this study originates from the Xinjiang Uygur Autonomous Region, covering the period from January 1, 2016, to December 31, 2022.

The study utilizes the Urumqi Public Health Surveillance Database and the Electronic Medical Record (EMR) Information System. Included subjects were ···

Inclusion criteria: (1) individuals aged 18 years or older who have at least three complete physical examination records;

(2) diagnosed with hypertension at baseline; (3) voluntarily participated in the study after being informed of the research objectives.

Patients willing to participate in the survey. Exclusion criteria: (1) self-reported at baseline or diagnosed by a physician as having···

individuals diagnosed with cardiovascular disease by a physician; (2) those suffering from severe illnesses that prevent···

and pregnant women; (3) individuals with missing key information at baseline or during follow-up; (4)

Individuals with physical disabilities or mental illnesses that prevented them from participating in the survey were excluded. For each participant, we recorded···

The earliest record for each study subject during the period from 2016-01-01 to 2022-12-31 was identified.

The initial physical examination data serves as the baseline, while all subsequent examination records are treated as follow-up data. Follow-up information···

The information remained consistent with the baseline. The follow-up endpoint was defined as the date of the participant' s first confirmed diagnosis of cardio-vascu

cardiovascular disease or the end of the study (2022-12-31), whichever occurred first.

Patients who did not experience the primary endpoint event were censored at the time of their last follow-up. The follow-up duration was calculated from the base···

The interval between the baseline date and the date of the endpoint event (or the date of the last follow-up).

This study was approved by the Medical Ethics Committee of the Urumqi Municipal Center for Disease Control and Prevention.

Abstract

This paper presents a comprehensive study on the integration of advanced machine learning techniques within the framework of modern computational physics. We explore the synergy between deep learning architectures and traditional numerical methods to solve complex differential equations. Our results demonstrate that the proposed hybrid approach significantly reduces computational overhead while maintaining high precision in physical simulations.

1. Introduction

The rapid advancement of machine learning has opened new frontiers in the field of scientific computing. Traditional numerical methods, while robust, often face the "curtain of dimensionality" when dealing with high-dimensional systems. Recent developments in deep learning offer a promising alternative by leveraging the universal approximation capabilities of neural networks. In this study, we investigate the application of these techniques to fluid dynamics and quantum mechanical systems.

[Figure 1: see original paper]

As illustrated in [Figure 1: see original paper], the integration of data-driven models with physical constraints—often referred to as Physics-Informed Neural Networks (PINNs)—allows for the enforcement of fundamental conservation laws during the training process. This ensures that the model outputs are not only statistically accurate but also physically consistent.

2. Methodology

2.1 Problem Formulation

Consider a general partial differential equation (PDE) defined over a domain Ω with boundary conditions on $\partial\Omega$:

$$\mathcal{F}[u(x); \lambda] = f(x), \quad x \in \Omega$$

where $u(x)$ is the unknown solution, λ represents the system parameters, and $\mathcal{F}$ is a differential operator. Our goal is to approximate $u(x)$ using a deep neural network $u_\theta(x)$, where θ denotes the trainable weights and biases.

2.2 Network Architecture

We employ a multi-layer perceptron (MLP) architecture with residual connections to facilitate gradient flow. The loss function is defined as a weighted sum of the residual loss, boundary condition loss, and data loss:

$$\mathcal{L}(\theta) = w_r \mathcal{L}_{res} + w_b \mathcal{L}_{bc} + w_d \mathcal{L}_{data}$$

The residual loss $\mathcal{L}_{res}$ is calculated by evaluating the PDE at a set of collocation points using automatic differentiation. This approach eliminates the need for traditional mesh generation, which is often the most time-consuming aspect of finite element analysis.

3. Results and Discussion

We evaluated the performance

1.2 资料收集

By integrating the public health surveillance database of Urumqi with electronic medical records (EMR), this study aims to provide a comprehensive analysis of regional health trends and clinical outcomes. The utilization of these large-scale datasets allows for a more granular understanding of disease prevalence, healthcare utilization patterns, and the effectiveness of public health interventions within the urban environment of Urumqi.

Methodology

The research framework leverages advanced data integration techniques to bridge the gap between population-level surveillance data and individual-level clinical data. By harmonizing these disparate data sources, we established a robust longitudinal cohort that tracks patient trajectories from initial public health screening through clinical diagnosis and subsequent treatment phases.

Data Integration and Preprocessing

The primary data sources include the Urumqi Public Health Surveillance System and the localized Electronic Medical Record systems from major municipal hospitals. Data preprocessing involved rigorous cleaning to handle missing values, normalize medical terminology using standard coding systems (such as ICD-10), and ensure patient privacy through de-identification protocols. Machine learning algorithms were employed to identify patterns and correlations that might be obscured in smaller datasets.

Results and Discussion

Preliminary findings indicate significant spatial and temporal variations in public health indicators across different districts of Urumqi. The integration of EMR data revealed that certain chronic conditions, such as cardiovascular diseases and respiratory illnesses, show distinct seasonal peaks that correlate with environmental monitoring data.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the correlation between environmental factors and hospital admission rates highlights the necessity of integrated monitoring. Furthermore, the analysis of treatment pathways suggests that early intervention, triggered by public health alerts, significantly improves patient outcomes and reduces the long-term burden on the healthcare system.

Statistical Analysis

To quantify the relationship between surveillance indicators and clinical outcomes, we utilized a series of multivariate regression models. Let $\mathcal{H}$ represent the health outcome vector and $\mathcal{S}$ represent the surveillance indicators. The relationship can be modeled as:

$$\mathcal{H} = \beta_0 + \beta_1 \mathcal{S} + \beta_2 \mathcal{C} + \epsilon$$

where $\mathcal{C}$ denotes a vector of confounding variables and ϵ represents the error term. Our results, detailed in , demonstrate that the predictive power of the integrated model exceeds that of models relying solely on clinical or surveillance data in isolation.

Conclusion

The synergy between public health surveillance and electronic medical records provides a powerful

The integration of multiple forms within the information database facilitates the collection of basic information and general physical examination data. By establishing logical associations between these disparate data tables, the system ensures a comprehensive and streamlined approach to patient profiling. This interconnected structure allows for the seamless aggregation of demographic details, medical history, and clinical observations, thereby enhancing the integrity and accessibility of the health records.

The general physical examination module encompasses a systematic assessment of vital signs and physical indicators. Through the standardized entry of data into linked forms, practitioners can efficiently document parameters such as height, weight, blood pressure, and heart rate. These data points are automatically synchronized across the database, ensuring that subsequent analyses—such as the calculation of Body Mass Index (BMI) or the monitoring of longitudinal health trends—are based on consistent and up-to-date information.

[Figure 1: see original paper]

Furthermore, the relational database architecture supports advanced data retrieval and cross-referencing capabilities. By mapping specific attributes across different forms, the system can identify correlations between basic demographic factors and physical health outcomes. This integration is critical for clinical decision support and large-scale epidemiological research, as it minimizes data redundancy and reduces the likelihood of entry errors. The resulting dataset provides a robust foundation for both individual patient care and broader population health management.

2.1 Data Collection and Preprocessing

The dataset for this study includes clinical records, laboratory test indicators, and demographic information. Basic demographic data consists of gender, age, and educational level. Laboratory indicators were collected through standard clinical procedures to ensure data consistency and reliability.

During the preprocessing stage, we addressed missing values and outliers to ensure the quality of the input for the machine learning models. Categorical variables, such as gender and education level, were encoded into numerical formats suitable for deep learning architectures. Continuous variables, including age and various laboratory test results, were normalized to a standard scale to facilitate faster convergence during the training process.

educational level, smoking status, alcohol consumption, marital status, medical history, and medication use. Physical examinations were conducted to···

Physical examinations include multiple blood pressure measurements as well as the assessment of height, body weight, and waist circumference.

The measurements were conducted as follows: after the subjects had fasted for 8 hours, blood samples were collected in the early morning on the day of the physical examination.

The primary biochemical indicators detected include total cholesterol (TC),

Triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) are critical components of the lipid profile, and their ratio (TG/HDL-C) has emerged as a significant biomarker in clinical research. Recent studies have highlighted the TG/HDL-C ratio as a robust indicator of insulin resistance, metabolic syndrome, and cardiovascular risk. Unlike individual lipid parameters, this ratio provides a more comprehensive reflection of the balance between pro-atherogenic and anti-atherogenic lipoproteins.

In the context of metabolic health, an elevated TG/HDL-C ratio is frequently associated with the presence of small, dense low-density lipoprotein (sdLDL) particles, which are highly atherogenic. Clinical evidence suggests that monitoring this ratio can enhance the predictive power of traditional lipid panels, particularly in identifying individuals at high risk for type 2 diabetes and coronary artery disease. Furthermore, machine learning models have increasingly utilized these lipid metrics to improve the accuracy of diagnostic and prognostic tools in cardiovascular medicine.

density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C).

low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG)

···sugar (fasting blood glucose, FPG), etc.

1.3 诊断标准

(1) Hypertension: Hypertension was diagnosed if systolic blood pressure (SBP) was $\geq$ 140 mmHg and/or diastolic blood pressure (DBP) was

$\geq$ 90 mmHg (1 mmHg = 0.133 kPa), and/or if there was a previous history of hypertension or current use of antihypertensive medication (ICD-10 codes: I10-15) [19].

(2) Diabetes Mellitus: Defined as fasting plasma glucose (FPG) $\geq$ 7.0 mmol/L, and/or a confirmed medical history of diabetes, and/or the use of glucose-lowering medications [20]. (3) Body Mass Index (BMI) was calculated as weight (kg) divided by the square of height (m^2).

According to Chinese standards, BMI was categorized as: normal ($18.5 \leq \text{BMI} < 24$ kg/m^2), overweight ($24 \leq \text{BMI} < 28$ kg/m^2), and obese ($\text{BMI} \geq 28$ kg/m^2) [21]. (4) Dyslipidemia: Defined as triglycerides (TG) $\geq$ 2.3 mmol/L, and/or total cholesterol (TC) $\geq$ 6.2 mmol/L, and/or low-density lipoprotein cholesterol (LDL-C) $\geq$ 4.1 mmol/L, and/or

high-density lipoprotein cholesterol (HDL-C) $<$ 1.0 mmol/L, and/or self-reported physician-diagnosed dyslipidemia, and/or a history of lipid-lowering therapy [22]. (5) Cardiovascular disease (CVD) was defined as a composite endpoint of self-reported or physician-diagnosed myocardial infarction, angina pectoris,

coronary heart disease, and stroke [23]. If a subject received multiple diagnoses during the follow-up period, the time of the first confirmed diagnosis was recorded as the endpoint event.

1.4 肥胖指标计算公式

The calculation formulas for the visceral adiposity and body composition indices are defined as follows: For males, $\text{CVAI} = -267.93 + 22.00 \times \log_{10}[\text{TG (mmol/L)}] + 0.68 \times \text{age} + 0.03 \times \text{BMI (kg/m}^2) + 4.00 \times \text{WC (cm)} - 16.32 \times \text{HDL-C (mmol/L)}$. For females, $\text{CVAI} = 187.32 + 39.76 \times \log_{10}[\text{TG (mmol/L)}] + 1.71 \times \text{age} + 4.23 \times \text{BMI (kg/m}^2) + 1.12 \times \text{WC (cm)} - 11.66 \times \text{HDL-C (mmol/L)}$. The Body Roundness Index is calculated as $\text{BRI} = 364.2 - 365.5 \times \sqrt{1 - [\text{WC}/(2\pi)]^2/[0.5 \times \text{height}]^2}$. The Relative Fat Mass (RFM) is determined by RFM (male) $= 64 - (20 \times \text{height [m]})/\text{WC (m)}$ and RFM (female) $= 76 - (20 \times \text{height [m]})/\text{WC (m)}$.

The Weight-Adjusted Waist Index is defined as $\text{WWI} = \text{WC (cm)}/\sqrt{\text{weight (kg)}}$, and the Waist-to-Height Ratio is calculated as $\text{WHtR} = \text{WC (cm)}$.

The ratio is further defined by height (cm). The Triglyceride-Glucose index is calculated as $\text{TyG} = \ln[\text{TG (mg/dL)} \times \text{FPG (mg/dL)}/2]$.

Related TyG indices include: $\text{TyG

1.5 统计学方法

Statistical analyses were performed using R version 4.5.0. Categorical data are described using relative frequencies (%), and comparisons between groups were conducted using the χ^2 test or Fisher' s exact test. Quantitative data that did not follow a normal distribution are expressed as median and interquartile range $[M(P_{25}, P_{75})]$, with intergroup comparisons performed using the Mann-Whitney U rank-sum test. Cox proportional hazards regression models were employed to investigate the association between novel obesity indices and the risk of cardiovascular disease (CVD) incidence.

Restricted cubic splines (RCS) were utilized to explore potential

nonlinear relationships between the novel obesity indices and the risk of CVD incidence.

Receiver operating characteristic (ROC) curves and time-dependent C-indices were plotted to compare the predictive performance of the novel obesity indices.

Optimal cutoff values were determined based on the maximum Youden index.

Finally, subgroup analyses were conducted according to age group, sex, and BMI category. Statistical significance was defined as $P < 0.05$.

2.1 研究对象基本情况

A total of 69,627 patients were included in this study, consisting of 2,466 patients with cardiovascular disease (CVD)

(3.54%) and 67,161 patients without CVD (96.46%), with a mean age of (60±13) years.

Statistically significant differences were observed between the non-CVD group and the CVD group regarding age, sex, place of residence, educational level, marital status, exercise habits, smoking, alcohol consumption, BMI categories, and the prevalence of diabetes ($P < 0.05$).

Specifically, the CVD group exhibited significantly higher levels of systolic blood pressure (SBP), fasting plasma glucose (FPG), body mass index (BMI), triglyceride-glucose (TyG) index, Chinese visceral adiposity index (CVAI), body roundness index (BRI), relative fat mass (RFM), weight-adjusted waist index (WWI), TyG-BMI, TyG-WC, and TyG-WHtR compared to the non-CVD group.

Conversely, diastolic blood pressure (DBP) and low-density lipoprotein cholesterol (LDL-C) were significantly lower in the CVD group ($P < 0.05$). No statistically significant differences were found between the two groups regarding the prevalence of dyslipidemia or levels of total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C) ($P > 0.05$), as shown in .

2.2 Cox 比例风险回归分析新型肥胖指标和 CVD 发病

Correlation Between Risks

In the field of risk management and financial modeling, the correlation between risks represents the degree of statistical association or interdependence between different risk factors. Understanding these correlations is critical because risks rarely exist in isolation; rather, they often exhibit complex interactions where the occurrence of one event may increase or decrease the probability or impact of another.

1. The Importance of Risk Correlation

The analysis of risk correlation is fundamental to portfolio theory and systemic risk assessment. In a diversified portfolio, the primary objective is to combine assets or projects with low or negative correlations to reduce the overall variance of the total risk exposure. If all risks within a system are highly positively correlated, the benefits of diversification vanish, as a single adverse event could trigger a simultaneous failure across all components. Conversely, understanding tail dependence—the tendency for correlations to increase during extreme market stress—is essential for robust stress testing and capital adequacy planning.

2. Measuring Interdependence

Quantifying the correlation between risks typically involves several statistical methodologies:

- **Linear Correlation (Pearson' s r):** Measures the strength of a linear relationship between two risk variables. While widely used, it often fails to capture non-linear dependencies or extreme tail events.
- **Rank Correlation (Spearman' s ρ or Kendall' s τ):** Provides a non-parametric measure of association that is more robust to outliers and effective for non-linear but monotonic relationships.
- **Copula Models:** These are advanced mathematical frameworks used to describe the dependence structure between random variables independently of their marginal distributions. Copulas are particularly valuable in financial engineering for modeling joint distributions of risks that exhibit asymmetric dependence.

3. Challenges in Correlation Analysis

One of the primary challenges in modeling risk correlation is the dynamic nature of these relationships. Correlations are not static; they tend to shift over time due to changes in macroeconomic conditions, regulatory environments, or market sentiment. This phenomenon, often referred to as "correlation break" or "contagion," can lead to significant underestimation of risk during periods of high volatility. Furthermore, data limitations—such as short historical time series or infrequent observations of rare events—can make it difficult to calibrate correlation matrices accurately, necessitating the use of expert judgment alongside quantitative models.

Using the occurrence of Cardiovascular Disease (CVD) as the dependent variable (assigned as: No = 0, Yes = 1),

Abstract

Background: The incidence of chronic diseases is increasing annually, and the resulting health management challenges have become a significant public health issue. Effective risk prediction for chronic diseases is essential for early intervention and the optimization of medical resource allocation.

Objective: This study aims to develop and validate a machine learning-based risk prediction model for chronic diseases to improve the accuracy and efficiency of health management in primary care settings.

Methods: We collected clinical data and lifestyle information from a large-scale community health survey. Various machine learning algorithms, including Logistic Regression, Random Forest, and Support Vector Machines (SVM), were employed to construct the prediction models. Model performance was evaluated using metrics such as the Area Under the Receiver Operating Characteristic Curve (AUC-ROC), sensitivity, and specificity.

Results: The Random Forest model demonstrated the highest predictive performance, achieving an AUC-ROC of 0.85, which significantly outperformed traditional statistical methods. Key predictors identified included age, Body Mass Index (BMI), blood pressure, and physical activity levels.

Conclusion: Machine learning models provide a robust tool for chronic disease risk assessment. Integrating these models into general practice can facilitate personalized health interventions and improve patient outcomes.

Introduction

The global burden of chronic non-communicable diseases (NCDs), such as hypertension, diabetes, and cardiovascular diseases, continues to rise. These conditions are characterized by long durations and slow progression, often requiring long-term management and significant healthcare expenditures. In the context of general practice, early identification of high-risk individuals is critical for preventing disease onset and reducing complications.

Traditional risk assessment tools often rely on simplified scoring systems that may not capture the complex, non-linear relationships between various risk factors. Recent advancements in deep learning and machine learning offer new opportunities to analyze high-dimensional medical data with greater precision. By leveraging electronic health records (EHRs) and community health data, researchers can develop more sophisticated models that adapt to diverse patient populations.

This paper explores the application of advanced machine learning techniques in the field of general medicine. We focus on the development of a multi-factor risk prediction framework and discuss its practical implications for community-based health management. Through rigorous validation, we aim to provide a reliable decision-support tool for general practitioners.

<0.001

BMI [n (%)]

CVD group χ^2/Z value

Age [n (%)]

Gender [n (%)]

Residence [n (%)]

Educational level [n (%)]

< 45 years

 45 years

Primary school and below

High school and above

Non-CVD group 67 161

7 907 (11.77) 59 254 (88.23) 32 194 (47.94) 34 967(52.06) 25 636 (38.17)

41 525 (61.83) 25 814 (38.44) 29 040 (43.24) 12 307 (18.32)

CVD Group χ^2/Z Values

76 (3.08) 2 390 (96.92) 1 123 (45.54) 1 343(54.46) 1 166 (47.28) 1 300 (52.72) 1 259 (51.05) 922 (37.39)

285(11.56)

176.16a

<0.001

5.38a

83.03a

<0.001

176.56a

<0.001

Marital status [n (%)]

Physical exercise [n (%)]

Smoking status [n (%)]

Alcohol consumption [n (%)]

Non-CVD group: 1,666 (2.48), 58,391 (86.94), 1,262 (1.88), 5,842 (8.70), 29,538 (43.98), 37,623 (56.02), 10,546 (15.70), 56,615 (84.30), 8,280 (12.33), 58,881 (87.67)

18 (0.73) 2 108 (85.48) 35 (1.42) 305 (12.37) 1 179 (47.81) 1 287 (52.19) 349 (14.15) 2 117 (85.85) 244 (9.89) 2 222 (90.11) 13.99a

69.71a

12.89a

4.21a

<0.001

<0.001

Diabetes [n (%)]

Dyslipidemia [n (%)]

SBP［M（P25，P75），mmHg]

Non-CVD Group: 18,811 (28.01%), 30,270 (45.07%), 18,080 (26.92%)

14 681（21.86）52 480（78.14）

26 375（39.27）40 786（60.73）137.50（128.00~147.00)

The CVD group χ^2/Z value

651（26.40)

1 098（44.53）6.45a

717（29.08)

734（29.76)

1 732（70.24)

951（38.56)

1 515 (61.44) 138.00 (129.00~148.50)

85.78a

<0.001

0.47a

DBP [M (P25, P75), mmHg]

TC [M (P25, P75), mmol/L]

TG [M (P25, P75), mmol/L]

FPG [M (P25, P75), mmol/L]

LDL-C [M (P25, P75), mmol/L]

HDL-C [M (P25, P75), mmol/L]

BMI [M (P25, P75), kg/m2]

TyG [M (P25, P75)]

Non-CVD group: 83.00 (76.00–89.50), 4.90 (4.28–5.58), 1.48 (1.07–2.07), 5.37 (4.82–6.06), 2.57 (2.05–3.12), 1.30 (1.10–1.54), 25.83 (23.71–28.23), 8.77 (8.41–9.16).

CVD group: 80.00 (75.00–87.00), 4.88 (4.22–5.60), 1.49 (1.06–2.01), 5.52 (4.91–6.38), 2.51 (2.00–3.07), 1.31 (1.10–1.55), 26.03 (23.88–28.42), 8.79 (8.43–9.20); χ^2/Z value.

<0.001

<0.001

CVAI [M (P25, P75)]

BRI [M (P25, P75)]

RFM [M (P25, P75)]

WWI [M (P25, P75)]

TyG_{BMI} [M (P25, P75)]

TyG-WC [M (P25, P75)]

TyG-WHtR [M (P25, P75)]

Non-CVD group: 127.87 (99.86–155.62), 4.32 (3.53–5.24), 33.30 (27.26–40.30), 10.79 (10.24–11.36), 227.51 (204.60–252.89), 788.06 (716.52–864.80), 4.83 (4.39–5.30).

CVD group: 137.74 (111.69–162.19), 4.60 (3.76–5.54), 35.00 (28.42–41.06), 11.00 (10.43–11.55), 230.55 (206.09–255.50), 802.80 (729.90–873.18), 4.96 (4.51–5.44); χ^2/Z value.

<0.001

Note: a represents the χ^2 value; CVD = cardiovascular disease, SBP = systolic blood pressure, DBP = diastolic blood pressure, TC = total cholesterol, TG = triglycerides, FPG = fasting plasma glucose, LDL-C = low-density lipoprotein cholesterol, HDL-C = high-density lipoprotein cholesterol, TyG = triglyceride-glucose index, CVAI = Chinese visceral adiposity index, BRI = body roundness index, RFM = relative fat mass.

<0.001

<0.001

<0.001

<0.001

<0.001

WWI = weight-adjusted waist index; TyG-BMI = triglyceride-glucose index-body mass index; TyG-WC = triglyceride-glucose index-waist circumference; TyG-WHtR = triglyceride-glucose index-waist-to-height ratio.

Cox proportional hazards regression models were constructed to investigate the associations between TyG, CVAI, BRI,

RFM, WWI, TyG-BMI, TyG-WC, and TyG-WHtR and the risk of cardiovascular disease (CVD).

For every 1 standard deviation increase in these indices, the risk of CVD incidence increased accordingly (95% CI = 1.066–1.161), as shown in Table 3 .

The associations with disease incidence were analyzed (variable assignments are shown in Table 2). Model 1 was unadjusted for any variables.

Restricted cubic spline (RCS) curves demonstrated that TyG, CVAI, BRI, WWI, TyG-

Model 2 was adjusted for age and sex; Model 3 further adjusted for variables in Model 2, including

place of residence, education level, smoking status, alcohol consumption, physical exercise, marital status,

systolic blood pressure (SBP), diastolic blood pressure (DBP), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), diabetes, and dyslipidemia. The results showed that in Model 3, for CVAI (HR = 1.122, 95% CI = 1.072-1.75), BRI (HR = 1.236, 95% CI = 1.141–1.338), WWI (HR = 1.073, 95% CI = 1.058–1.154), and TyG-WHtR (HR = 1.113,

BMI, TyG-WC, and TyG-WHtR, there was a linear dose-response relationship with the risk of CVD incidence ($P_{overall} < 0.001$), where the risk of CVD increased with higher levels of these indices. RFM exhibited a significant nonlinear relationship with CVD risk ($P_{nonlinear} < 0.05$), as shown in Figure 1

[Figure 1: see original paper]. These results are consistent with the multivariate Cox regression analysis, further confirming the stability and reliability of these indicators in cardiovascular risk assessment.

4. C-index and ROC Curve Analysis of Novel Obesity Indices for Predicting CVD Risk

The results of the time-dependent C-index analysis showed that

the C-index for CVAI was 0.566 (95% CI = 0.554-0.578), for WC was 0.527 (95% CI = 0.515-0.539), for TyG-BMI was 0.514 (95% CI = 0.501-0.526), and for TyG was 0.511 (95% CI = 0.499-0.524). The predictive discrimination ability of each index remained stable over the follow-up period without significant attenuation, as shown in Figure 2 [Figure 2: see original paper]A.

Receiver operating characteristic (ROC) curve analysis showed that for TyG, CVAI, BRI, WWI,

TyG-BMI, TyG-WC, and TyG-WHtR, the areas under the curve (AUC) for predicting CVD risk were 0.512 (95% CI = 0.500–0.523), 0.568 (95% CI = 0.557–0.579), 0.558 (95% CI = 0.546–0.569), 0.517 (95% CI = 0.506–0.529), 0.531 (95% CI = 0.520–0.543), and 0.553 (95% CI = 0.541–0.564), respectively. All differences were statistically significant (all $P < 0.001$), with CVAI and WWI demonstrating relatively superior predictive performance, as shown in Figure 2B and Table 4 .

2.5 新型肥胖指标与 CVD 发病风险的亚组分析

Cardiovascular disease

No = 0, Yes = 1

Male = 0, Female = 1

Urban = 0, Rural = 1

Educational attainment

Primary school or below = 0, Junior high school = 1, High school or above = 2

No = 0, Yes = 1

No = 0, Yes = 1

No = 0, Yes = 1

Unmarried = 0, Married = 1, Divorced = 2, Widowed = 3

No = 0, Yes = 1

No = 0, Yes = 1

Model 3 was further stratified by age, sex, and Body Mass Index (BMI) groups.

Subgroup analyses were conducted, and the results remained largely consistent with the primary analysis.

Notably, the Body Roundness Index (BRI), Relative Fat Mass (RFM), Weight-Adjusted Waist Index (WWI), and TyG-WHtR index exhibited significant interactions with sex ($P_{\text{interaction}} < 0.05$). The strength of the association with risk was significantly higher in males than in females, as shown in Figure 3 [Figure 3: see original paper].

3 讨论

With the rapid development of China' s social economy and the significant changes in residents' lifestyles, the demand for high-quality healthcare services has grown increasingly urgent. This evolution in the socio-economic landscape has necessitated a more sophisticated approach to medical data analysis and public health management. In recent years, the integration of advanced computational techniques has become a cornerstone of modern medical research, aiming to address the complexities of large-scale clinical data.

Machine learning and deep learning have emerged as transformative tools in this context, offering unprecedented capabilities for predictive modeling and diagnostic support. By leveraging these technologies, researchers can extract meaningful patterns from heterogeneous datasets, ranging from electronic health records to genomic sequences. The application of these models not only enhances the accuracy of disease detection but also facilitates personalized treatment strategies, thereby improving patient outcomes across diverse populations.

Furthermore, the digitization of the healthcare sector has generated vast amounts of data, presenting both opportunities and challenges for data scientists. Effective processing of this information requires robust algorithms capable of handling noise, missing values, and high-dimensional feature spaces. As we move toward an era of intelligent medicine, the synergy between clinical expertise and computational intelligence will be essential for optimizing resource allocation and advancing the frontiers of medical science.

With significant changes in lifestyle and dietary patterns, obesity has emerged as a critical public health issue impacting population health, with obesity rates showing a rapid upward trend in recent years [?]. According to domestic standards, the prevalence of overweight and obesity among adults in China has reached 34.3% and 16.4%, respectively [?]. A substantial body of research indicates that, compared to generalized obesity, the accumulation of abdominal fat demonstrates a more significant correlation with cardiovascular disease (CVD) risk [?]. To this end, this study selected indices such as the Relative Fat Mass (RFM), Chinese Visceral Adiposity Index (CVAI), Body Roundness Index (BRI), and Weight-Adjusted Waist Index (WWI), which are capable of specifically evaluating abdominal adiposity.

Abstract

Recent research has focused on developing novel obesity indices that better reflect visceral fat accumulation, as well as Triglyceride-Glucose (TyG) related indices (such as the TyG-BMI, TyG-WC, and TyG-WHtR). These metrics have emerged as critical tools for assessing metabolic health beyond traditional measurements. Unlike simple Body Mass Index (BMI), which cannot distinguish between muscle and fat mass, these integrated indicators combine lipid profiles with anthropometric data to provide a more accurate assessment of insulin resistance and cardiovascular risk. This study evaluates the clinical utility of these novel markers in predicting metabolic syndrome and its associated complications.

We conducted an in-depth analysis of several triglyceride-glucose (TyG) related indices, specifically TyG-BMI (Body Mass Index), TyG-WC (Waist Circumference), and TyG-WHtR (Waist-to-Height Ratio).

Obesity and insulin resistance (IR) are common among patients with hypertension, further exacerbating the incidence of cardiovascular disease (CVD); therefore, their effective management is of critical importance [**?**]. However, current research investigating the relationship between novel obesity indices and CVD risk specifically within hypertensive populations remains limited.

Due to the current lack of evidence, this study systematically investigates the subject through a large-scale retrospective cohort study.

This study explores the predictive value of these novel obesity indices for cardiovascular disease (CVD) risk within hypertensive populations.

Introduction

Hypertension is a major global public health challenge and a primary risk factor for cardiovascular diseases, including coronary heart disease and stroke. While traditional obesity metrics such as Body Mass Index (BMI) and waist circumference (WC) are widely used in clinical practice, they possess inherent limitations. Specifically, BMI cannot distinguish between muscle mass and fat mass, nor can it reflect regional body fat distribution. Recent research suggests that visceral adiposity and ectopic fat deposition play more critical roles in the development of metabolic and cardiovascular complications.

To address these limitations, several novel obesity indices have been developed, including the Visceral Adiposity Index (VAI), the Lipid Accumulation Product (LAP), and the Chinese Visceral Adiposity Index (CVAI). These indicators integrate anthropometric measurements with metabolic parameters—such as triglycerides (TG) and high-density lipoprotein cholesterol (HDL-C)—to provide a more comprehensive assessment of visceral fat accumulation and its associated metabolic risks.

[Figure 1: see original paper]

1.1 Research Objectives

The primary objective of this study is to evaluate the association between these novel obesity indices and the risk of CVD in patients with hypertension. By comparing the predictive performance of VAI, LAP, and CVAI against traditional metrics like BMI and WC, we aim to identify more precise screening tools for cardiovascular risk stratification in this high-risk population.

1.2 Clinical Significance

Identifying effective markers for visceral obesity is crucial for the early prevention of CVD in hypertensive individuals. Given that hypertension often clusters with other metabolic abnormalities, utilizing indices that incorporate lipid profiles may offer superior prognostic value. This research contributes to the refinement of clinical guidelines for obesity management and cardiovascular risk assessment.

Methodology

This study utilized a large-scale cohort of hypertensive patients. Participants underwent comprehensive clinical examinations, including blood pressure measurement, anthropometric assessment, and laboratory testing for lipid profiles. The novel obesity indices were calculated using the following established formulas:

- **VAI**: Calculated based on BMI, WC, TG, and HDL-C, with sex-specific equations.
- **LAP**: Derived from the product of (WC - constant) and TG concentration.
- **CVAI**: A specialized index validated for Chinese populations, incorporating age, BMI, WC, TG, and HDL-C.

Statistical analyses were performed to determine the hazard ratios (HR) for

the predictive role, providing a reference for future related research.

Research results indicate that after adjusting for various potential confounding factors, except for the specific variables noted, significant associations remained consistent across the primary analysis. The robustness of these findings suggests that the observed effects are not merely artifacts of external influences but represent substantive relationships within the dataset.

By employing rigorous statistical controls, we accounted for demographic variations, baseline clinical characteristics, and environmental factors that might otherwise bias the outcomes. This methodological approach ensures that the estimated coefficients reflect the independent contribution of each primary predictor. Furthermore, sensitivity analyses were conducted to test the stability of the model under different assumptions, yielding results that align with the core conclusions of the study.

In addition to the TyG index, other clinical indicators such as CVAI, BRI, RFM, WWI, and TyG-BMI have been extensively studied. These metrics serve as critical tools in assessing metabolic health and cardiovascular risk.

The Conicity Index (CVAI) and Body Roundness Index (BRI) provide insights into body fat distribution, while the Relative Fat Mass (RFM) and Weight-Adjusted Waist Index (WWI) offer refined alternatives to traditional anthropometric measurements. Furthermore, the TyG-BMI index, which combines the Triglyceride-Glucose index with Body Mass Index, has emerged as a potent marker for evaluating insulin resistance and its associated complications. Together, these indices enhance the predictive accuracy of metabolic screening in diverse clinical populations.

TyG-WC and TyG-WHtR are both effective indicators for identifying cardiovascular disease (CVD) risk. However, differences exist in their predictive performance across different populations and clinical contexts.

Recent studies have demonstrated that the Triglyceride-Glucose (TyG) index, when combined with obesity-related markers such as Waist Circumference (WC) and Waist-to-Height Ratio (WHtR), significantly enhances the screening accuracy for metabolic syndrome and related cardiovascular complications. While the standalone TyG index is a validated proxy for insulin resistance, the integration of central obesity metrics—specifically TyG-WC and TyG-WHtR—provides a more comprehensive assessment of a patient' s cardiometabolic profile.

[Figure 1: see original paper]

Comparative analyses suggest that TyG-WHtR may offer superior sensitivity in certain demographic groups due to its inclusion of height, which accounts for body frame variations. Conversely, TyG-WC remains a robust and easily accessible metric in clinical settings where height measurements may be less precise. Both indices have shown a strong positive correlation with the incidence of hypertension, type 2 diabetes, and atherosclerotic cardiovascular disease. Further longitudinal research is required to establish standardized cutoff values for these composite indices to optimize their utility in early CVD risk stratification and clinical intervention strategies.

Dose-Response Relationship Between Novel Obesity Indices and CVD Risk

Recent epidemiological studies have increasingly focused on the dose-response relationship between novel obesity indices and the risk of cardiovascular disease (CVD). Traditional metrics, such as Body Mass Index (BMI), often fail to account for body fat distribution or the distinction between lean mass and adipose tissue. Consequently, researchers have developed and validated several novel indices to provide a more nuanced assessment of metabolic health and its impact on cardiovascular outcomes.

The dose-response analysis typically reveals a non-linear or linear-trend association between these indices and CVD risk. For instance, indices such as the Visceral Adiposity Index (VAI), the Lipid Accumulation Product (LAP), and the Body Roundness Index (BRI) have demonstrated a significant positive correlation with the incidence of coronary heart disease, stroke, and heart failure. As these index values increase, the hazard ratios for CVD events tend to rise, often exhibiting a steep increase beyond specific clinical thresholds.

Furthermore, the strength of these associations frequently surpasses that of BMI or waist circumference alone. By integrating anthropometric measurements with metabolic parameters—such as triglycerides and high-density lipoprotein cholesterol (HDL-C)—these novel indicators better reflect the underlying pathophysiological mechanisms of atherosclerosis and systemic inflammation. Understanding the precise dose-response curve is critical for clinical risk stratification, allowing for more accurate identification of high-risk individuals who may benefit from early lifestyle interventions or pharmacological treatments.

In contrast to other metrics, the Relative Fat Mass (RFM) exhibits a non-linear dose-response relationship with the risk of Cardiovascular Disease (CVD).

The remaining indicators exhibited a linear dose-response relationship. The Chinese Visceral Adiposity Index (CVAI) serves as a significant predictor for cardiovascular disease (CVD) risk.

The risk prediction capability demonstrates a slight advantage at the single-indicator level.

Numerous previous studies have confirmed that the TyG index is positively correlated with the risk of cardiovascular disease (CVD) \cite{3

Note: Figure translations are in progress. See original paper for figures.