Trends in hypertension prevalence among adults aged ≥40 years in Agincourt, South Africa (2014 - 2022)

Z L Mondlane,[1,2] BCMP, MPH; **O Dewa,**[1†] MPH, PhD; **S M Patrick,**[1] MSc, PhD

[1] *School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria, South Africa*
[2] *SAMRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa*
[†] *Deceased*

Corresponding author: *S M Patrick (sean.patrick@up.ac.za)*

Background. Hypertension is a leading cause of cardiovascular disease. There are limited longitudinal data on temporal trends in hypertension prevalence in rural South Africa (SA).
Objectives. To analyse trends in hypertension prevalence and investigate its associated factors among adults aged ≥40 years in SA.
Methods. A retrospective observational secondary quantitative analysis of a sample from the Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI) was conducted. Data for the HAALSI study were collected over three waves during 2014, 2018 and 2021 from the existing Agincourt Health and Socio-demographic Surveillance System (AHDSS) framework, with a total sample of 3 707 participants in the present study. Descriptive statistics were used to summarise sociodemographic data. A bivariate analysis and multivariable generalised estimating equation (GEE) model was applied to determine factors associated with hypertension prevalence, with significance set at $p<0.05$.
Results. The overall prevalence of hypertension declined from 58% (95% confidence interval (CI) 56.42 - 59.58) in wave 1 to 42% (95% CI 40.42 - 43.58) in wave 2, and further decreased to 30% (95% CI 28.58 - 31.42) in wave 3. Transitions between hypertensive and normotensive status were observed, with 1 018 individuals transitioning to normotensive from wave 1 to wave 2, and 1 167 individuals from wave 2 to wave 3. The GEE analysis identified significant predictors of hypertension. High body mass index (BMI) was associated with increased odds in wave 2 (adjusted odds ratio (aOR) 1.11; 95% CI 1.02 - 1.21; $p=0.014$). Frequent alcohol consumption increased the odds of hypertension in wave 3 (aOR 1.19; 95% CI 1.04 - 1.37; $p=0.009$). No formal education was associated with higher hypertension prevalence (aOR 1.07; 95% CI:1.00 - 1.14; $p=0.0026$). Younger age (40 - 49 years) was protective, with decreased odds of hypertension in wave 2 (aOR 0.64; 95% CI 0.48 - 0.84; $p=0.014$), as was employment (aOR 0.82; 95% CI 0.69 - 0.96; $p=0.020$) and fruit consumption in wave 3 (aOR 0.95; 95% CI 0.91 - 0.99; $p=0.037$).
Conclusion. The study found that the prevalence of hypertension in Agincourt decreased from 58 to 30% between waves 1 and 3. High BMI, high alcohol use frequency and no formal education were key predators of hypertension. The study highlights the need for targeted public health interventions, including regular hypertension screening, lifestyle modification and better management of associated factors. These efforts will be crucial in reducing hypertension-related morbidity and mortality in rural SA.

Keywords: Agincourt, hypertension, prevalence, risk factors, South Africa

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Hypertension is a chronic medical condition characterised by consistently elevated arterial pressure levels.[1] The condition can be classified into two categories: primary hypertension, which is idiopathic (unknown) and accounts for the majority of cases, and secondary hypertension, which results from an underlying medical condition such as kidney disease, endocrine disorders, or the use of certain medications (e.g. steroids).[2] Primary hypertension accounts for 90 - 95% of cases, and has no identifiable cause.[3] It is associated with various risk factors including age, genetic predisposition, dietary habits, physical inactivity and psychosocial stress.[2-4]

According to the American Heart Association, hypertension is diagnosed when blood pressure readings are constantly >130/80 mmHg.[5] Blood pressure is quantified in millimetres of mercury (mmHg) and recorded as two numbers: systolic blood pressure (SBP; the higher number), which gauges the pressure in the arteries during heart contractions, and diastolic blood pressure (DBP; the lower number), which gauges the pressure in the arteries during heart relaxation.[6] Furthermore, genetic predisposition is significant, with a family history of hypertension increasing the risk of the condition.[7]

Globally, hypertension affects ~1.39 billion adults aged 30 - 79 years, with two-thirds of these living in low- and middle-income countries where healthcare systems often struggle to diagnose and manage hypertension effectively.[1,4] In sub-Saharan Africa (SSA), hypertension poses a considerable challenge, with an estimated 74.7 million living with the condition. This is expected to rise to 125.5 million by 2025.[8] Furthermore, it is predicted that hypertension in the SSA population will increase to 216.8 million by 2030.[8] This region is already strained by combatting infectious diseases such as malaria and HIV, and it has limited resources to address the growing burden of chronic conditions such as hypertension.[9]

In South Africa (SA), national surveys have reported a hypertension prevalence ranging from 38.4% in 2012 (the SA National Health and Nutrition Examination Survey) to 48.2% in 2016 (the Demographic and Health Survey).[10,11] Rural hypertension rates exceed those in most urban areas by >10%, with the 2017 Behavioural Risk Factor Surveillance System showing that 40% of participants in rural areas reported having hypertension, but 29.4% in urban areas.[12]

The Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in SA (HAALSI) provides important insight into hypertension prevalence and associated factors among older adults in rural SA. The HAALSI study uses a population-based survey to examine health, physical and cognitive function, ageing, cardiometabolic disease, associated factors and wellbeing among older men and women.[13]

The present study is relevant in light of the 2018 report on non-communicable diseases (NCDs) in SA, which highlights the growing burden of NCDs, including hypertension, in both urban and rural areas.[14] The 2018 NCD report identified hypertension as a significant contributor to mortality and morbidity, particularly in rural areas where access to healthcare is limited.[15]

The study aligns with the objectives of SA's National Strategic Plan for NCDs 2022 - 2027, which emphasises the need for comprehensive strategies to combat hypertension and other non-communicable diseases.[15] The plan outlines specific goals to improve the diagnosis, treatment and management of NCDs in resource-constrained areas.[15] By assessing hypertension trends and associated factors in a rural context, this study contributes to the broader national efforts to curb the rising burden of NCDs and improve health outcomes in SA.[15]

The study aligns with the Sustainable Development Goals (SDGs), particularly SDG 3 (good health and wellbeing) by contributing to the reduction of NCD mortality, and SDG 10 (reduced inequalities) by addressing health disparities in rural SA.[16] Strengthening public health interventions, community-based strategies and healthcare access will be essential to sustaining the observed decline in hypertension prevalence, and ensuring equitable management across all populations.

Despite the global and regional burden of hypertension and cardiovascular disease, and particularly that in rural SA, longitudinal studies assessing hypertension trends in rural SA remain limited. This study is one of the few that uses longitudinal, individual-level data from a population-based rural cohort to examine transitions in hypertension prevalence over time. Unlike many cross-sectional studies, it provides insights into how individual hypertension status changes over nearly a decade. This adds practical value for designing sustainable, rural-specific interventions in SA.

Methods

Study design

The study employed a retrospective observational quantitative analysis of secondary data extracted from the HAALSI study.[13]

Study setting

The current study analysed HAALSI data collected through the Agincourt Health and Demographic Surveillance System (AHDSS), a surveillance system operated by the South African Medical Research Council (SAMRC) and Wits Rural Public Health and Health Transitions Research Unit (Agincourt). Agincourt is located in rural Bushbuckridge, Mpumalanga, ~500 km north-east of Johannesburg. The research site comprises roughly 120 000 individuals residing in 21 000 households and 31 villages, spread over 450 km^2. One-third of the permanent population comprises former Mozambican refugees who immigrated to SA during the 1980s, and most of the population is Xitsonga-speaking. The study area consists of one community health centre and six government-run primary healthcare clinics. Referred patients usually use public transport to travel to one of three district hospitals (Mapulaneng, Matikwana and Tintswalo), which are 25 - 55 km away from the site (Fig. 1).[17]

Study population and sampling

The HAALSI study is a population-based survey implemented by the Harvard Center for Population and Development Studies and Agincourt, of the University of the Witwatersrand. HAALSI aims to examine and characterise a population of older men and women in rural SA concerning health, physical and cognitive function, ageing and wellbeing, in harmonisation with other health and retirement studies.

The target population was individuals aged ≥40 years who participated in all three waves of the HAALSI study (wave 1: 2014 - 2015, wave 2: 2018 - 2019, wave 3: 2021 - 2022). HAALSI initially recruited 5 059 individuals in wave 1. Of these, 3 707 participants had complete and linked data across all three waves relevant to this analysis. Participants were linked using a unique identifier assigned by the HAALSI platform. The HAALSI study employed random sampling from the AHDSS.[13] This study utilised data from the HAALSI dataset to focus on hypertension prevalence trends and associated risk factors. A sample size of 3 707 records were assessed to achieve a 95% statistical power for detecting significant differences using a one-sided 0.05 significance test. This calculation was conducted on G-Power statistical software incorporating an effect size of 0.1 and a precision level of 5%.

Measurements

Data for this study were extracted from the HAALSI website for wave 1, wave 2 and wave 3 surveys. The HAALSI survey tool was designed to collect data on participants' demographic characteristics, lifestyle factors and cardiometabolic health measurements. Demographic data included variables such as age, gender, education level, employment status and survey wave. Lifestyle factors included dietary habits, smoking status, alcohol consumption, physical activity and sedentary behaviour. Cardiometabolic measurements included body mass index (BMI), diabetes status and direct blood pressure measurements for hypertension assessment.

BMI was categorised using standard classifications: underweight (<18.5), normal weight (18.5 - 24.9), overweight (25 - 29.9), obese (30 - 34.9) and morbidly obese (>35). High BMI was defined as a BMI ≥25, indicating excessive adipose tissue accumulation associated with increased health risks.[1] Hypertension data were based on direct blood pressure measurements taken during each survey. We dichotomised and classified participants with hypertension based on World Health Organization (WHO) guidelines as either hypertensive (yes; systolic ≥140 mmHg or diastolic ≥90 mmHg) or normotensive (no; systolic ≤130 mmHg or diastolic ≤80 mmHg).[1]

Access to the HAALSI data was granted through a formal data use agreement, permitting the download of the longitudinal codebook and Stata (StataCorp, USA) data files in DTA format. Variables relevant to the current study, including demographic characteristics, lifestyle factors and cardiometabolic health data, were extracted and imported into a password-protected Excel spreadsheet (Microsoft, USA) for initial organisation and validation before analysis in Stata.

Data collection and analysis

The data collection process was conducted in a stepwise manner. Data were extracted from the HAALSI dataset across three waves, including measurements used to calculate the dependent variable (hypertension) and independent variables such as age, gender, education level, employment status, wave period, dietary habits, smoking status, alcohol consumption, physical activity, sedentary behaviour, BMI and diabetes status. Datasets from all three waves were merged using a pre-existing participant unique identifier automatically allocated by the HAALSI database to each unique participant to create a comprehensive dataset for analysis.

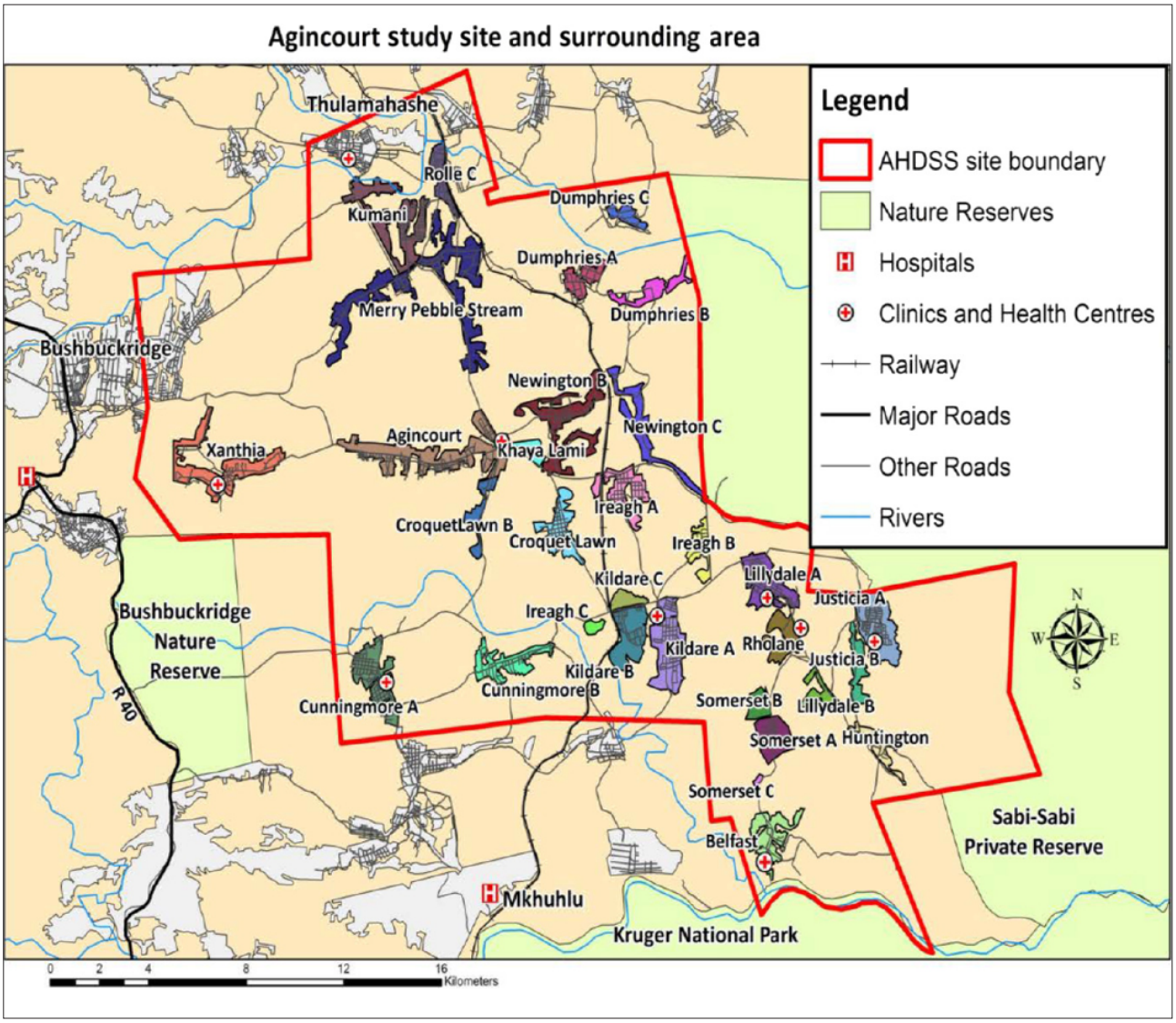

Fig. 1. Agincourt Health and Demographic Surveillance System (AHDSS) map.[17]

Categorical variables such as edu_level, w1emp_status, w1phy_act and w1exe_freq had missing values. Missing values were replaced with the string 'Unknown' to retain dataset completeness without discarding rows. This avoids bias while ensuring that all categories remain accounted for during analysis. Numeric variables such as w1sys_bp, w1dia_bp and w2sys_bp had missing values. Missing values in numeric columns were filled with their median values. The median is less sensitive to outliers compared with the mean, providing a robust imputation method. After imputation, the dataset was reviewed to confirm that there were no remaining missing values in the dataset by summarising the counts of missing values. The cleaned dataset was password-protected and saved as an Excel file.

Data were imported into and analysed using Stata version 18 software. Statistical analysis included analysing temporal trends in hypertension prevalence and associated risk factors, and 95% confidence intervals (CIs). Descriptive statistics, including counts and percentages, were used to summarise categorical data. Hypertension status was computed as a binary variable (0=normotensive, 1=hypertensive) based on systolic and diastolic blood pressure measurements categorised using the WHO guidelines (SBP ≥140 mmHg or DBP ≥90 mmHg).

To model the longitudinal associations, a generalised estimating equation (GEE) model was applied. GEEs were selected over mixed-effects models because they estimate population-averaged effects, which aligns with our aim of examining average trends across a rural population rather than individual-specific trajectories. An unstructured correlation method was used to flexibly model the varying correlations between repeated measurements for the same individuals across the three waves. This approach allows for more accurate estimation when correlations are not constant.

Bivariate analysis (χ^2 tests) assessed associations between hypertension and independent variables per wave. Variables with a p-value ≤0.2 in bivariate analyses, or those significant in at least one wave, were included in the multivariable models. Variables were also selected based on prior literature and theoretical importance to ensure clinical relevance.[18] Multicollinearity tests ensured that only non-collinear variables were entered into the models. Age_80+_w2 and 3 were excluded due to high collinearity.

Multivariable GEE was employed to model longitudinal associations between hypertension and associated factors, using a binary logit link function to estimate population-averaged effects, with a correlation set as unstructured. Adjusted odds ratios (aORs) with 95% CIs were reported for significant variables in the GEE

models. Confounders such as gender and sedentary_beh were adjusted for the multivariable GEE model to control for potential bias. Sensitivity analyses were performed with alternative definitions of hypertension, including stage 1 (SBP 140 - 149 mmHg or DBP 90 - 99 mmHg) and stage 2 (SBP ≥160 mmHg or DBP ≥100 mmHg). The GEE model was stratified by subgroups, such as age group (<60 and ≥60 years), gender (male and female) and BMI category (underweight, normal weight, overweight and obese). The GEE model was assessed using quasi-likelihood under the independence model criterion. Significance was set at $p<0.05$.

Ethical approval

The study received ethics approval from the University of Pretoria Faculty of Health Sciences Research Ethics Committee before it was conducted (ref. no. 420/2024). The data use agreement was obtained from HAALSI for de-identified human subject data.

Results

Demographic characteristics

In wave 1, the mean (standard deviation (SD)) age ranged from 44.62 (2.60) years among participants aged 40 - 49 to 73.90 (2.62) years among those aged 70 - 79, with interquartile ranges (IQRs) spanning 4 - 5 years. By wave 2, mean ages increased slightly within all groups, ranging from 46.58 (1.60) years in the 40 - 49 age group to 85.95 (5.05) years in the >80 group, with IQRs between 3 and 7 years. In wave 3, the age distribution showed similar trends, with mean (SD) ages ranging from 48.09 (0.81) years in the 40 - 49 age group to 86.41 (5.52) years in the >80 group, with IQRs spanning 2 - 8.5 years. The majority were female (56.73%, *n*=2 103/3 707). In terms of employment status, employed individuals decreased from 17.32% (*n*=642) to 10.14% (*n*=376), and unemployed individuals increased from 71.97% (*n*=2 668) to 89.86% (*n*=3 331). The majority of the participants had no formal education (43.59%, *n*=1 616), some had obtained primary education (grade 1 - 7; 35.01%, *n*=1 298/3 707), some had obtained some secondary level of education (grade 8 - 11; 12.41%, *n*=460/3 707) and some had obtained secondary or higher (grade 12+; 8.98%, *n*=333). Table 1 summarises participants' demographic characteristics and outcomes across all waves.

Changes in trends

Across the waves, the majority of participants reported excessive salt use: 60%, *n*=2 224 in wave 1, decreasing to 40%, *n*=1 482 in wave 2, and further decreasing to 20%, *n*=741 in wave 3. In wave 1, 23% (*n*=1 867) consumed soft drinks once daily, while 28%, *n*=1 042 participants consumed them twice. By wave 3, the highest frequency (30%) shifted to zero consumption, *n*=1106. Daily fruit intake (coded as 7: high) was reported by 8% (*n*=295) in wave 1, 6% (*n*=231) in wave 2, and 4% (*n*=135) in wave 3. Similarly, daily vegetable intake decreased from 5% (*n*=187) in wave 1 to 2% (*n*=71) in wave 3, with most participants reporting lower or inconsistent consumption patterns. Daily alcohol consumption (coded as 1) declined over the waves, from 3% (*n*=124) in wave 1 to 2% (*n*=72) of participants in wave 3. Most participants reported minimal alcohol use, with the proportion in the 'less than once per month' category (coded as 5) decreasing from 5% (*n*=177) in wave 1 to 1% (*n*=33) in wave 3, suggesting a reduction in occasional drinking over time. Most participants in all waves reported 'unknown' alcohol quantities. Among those who disclosed quantities, the proportion consuming 1 - 2 drinks (coded as 2) increased to 6% (*n*=211) in wave 3 from 1% (*n*=8) in wave 1.

Fig. 2 illustrates the changes in the key health and behavioural variables across three waves. Hypertension prevalence decreased from 58% (*n*=2 150) in wave 1 to 30% (*n*=1 112) in wave 3. Overweight individuals increased from 27.68% (*n*=1 026) in wave 1 to 51.93% (*n*=1 925) in wave 3, with a decrease in both normal weight and obese individuals across the three waves. Diabetic individuals increased from 10% (*n*=359) in wave 1 to 17% (*n*=617) in wave 3.

Changes in hypertension status

Table 2 summarises the changes in hypertension status from wave 1 to wave 2 and wave 2 to wave 3. The changes in hypertension status across waves are not statistically significant for either wave 1 to wave 2 or wave 2 to wave 3. Individuals' transitions between hypertensive and normotensive categories are strongly influenced by their initial status, with the majority of the individuals transitioning to normotensive. Proportions are included alongside absolute values. These changes were statistically significant (Pearson χ^2 $p<0.001$ for both transitions).

Multivariable GEE analysis

The results of the GEE analysis revealed several significant associations. Table 3 presents the odds ratios (ORs) and aORs and 95% CIs, and their corresponding *p*-values. The OR and aOR reflect the strength of association between each variable and the outcome (hypertension in this context), with values >1 indicating increased odds, and values <1 indicating decreased odds.

The table summarises the significant variables in one or more waves of the bivariate analysis, and multivariable GEE analysis, identifying factors associated with hypertension, with wave 1 as a reference.

Sensitivity analysis

Fig. 3 below illustrates the sensitivity analysis by subgroups. ORs were estimated using GEE: obesity, gender and age ≥60 years, which were statistically significant in either wave. Stage 1 hypertension is defined as SBP 140 - 149 mmHg or DBP 90 - 99 mmHg (yellow bars), and stage 2 hypertension as SBP ≥160 mmHg or DBP ≥100 mmHg (orange bars). The horizontal dashed line at OR=1 represents no increased odds. Obese individuals have higher odds of both stage 1 and stage 2 hypertension. Males and individuals aged ≥60 years have higher odds of stage 1 hypertension.

Discussion

The study's objectives were to examine temporal trends of hypertension prevalence and its associated factors among adults aged ≥40 years in Agincourt Health and Demographic Surveillance System (HDSS) from 2014 to 2022. The results of this study revealed a significant decline in hypertension prevalence over time, with an increase in normotensive individuals. Key predictors of hypertension included high BMI, frequent alcohol consumption and no formal education.

This analysis is one of the few to leverage repeated measures from a rural SA cohort. It allows us to observe within-individual transitions in hypertension status – an advantage over prior cross-sectional surveys. These findings support public health policy that is responsive to longitudinal risk patterns rather than snapshots.

The observed decline in hypertension prevalence over time may reflect improvements in awareness, screening and management strategies in the Agincourt HDSS. These trends align with SA's national Strategic Plan for Non-Communicable Disease (2022 - 2027), which emphasises early detection and lifestyle modification to reduce hypertension-related morbidity.[16]

Age group 1 (40 - 49 years) was associated with lower odds of hypertension in wave 2 ($p=0.014$). This finding is consistent with existing literature, which reports that hypertension prevalence tends

Table 1. Demographic characteristics summary (*N*=3 707)

Category	Wave 1, *n* (%)	Wave 2, *n* (%)	Wave 3, *n* (%)
Population size	3 707	3 707	3 707
Age group, years			
40 - 49	738 (19.91)	480 (12.95)	266 (7.18)
50 - 59	1 092 (29.46)	967 (26.09)	894 (24.12)
60 - 69	997 (26.90)	1 084 (29.24)	1 068 (28.81)
70 - 79	591 (15.94)	736 (19.85)	848 (22.88)
≥80	289 (7.80)	440 (11.87)	631 (17.02)
Gender			
Male	1 604 (43.27)	1 604 (43.27)	1 604 (43.27)
Female	2 103 (56.73)	2 103 (56.73)	2 103 (56.73)
Employment			
Employed	642 (17.32)	606 (16.35)	376 (10.14)
Unemployed	2 668 (71.97)	3 029 (81.71)	3 331 (89.86)
Self-employed	387 (10.44)	60 (1.62)	0
Unknown	10 (0.27)	12(0.32)	0
Education			
No formal education	1 616 (43.59)	1 616 (43.59)	1 616 (43.59)
Some primary	1 298 (35.01)	1 298 (35.01)	1 298 (35.01)
Some secondary	460 (12.41)	460 (12.41)	460 (12.41)
Secondary or higher (tertiary)	333 (8.98)	333 (8.98)	333 (8.98)

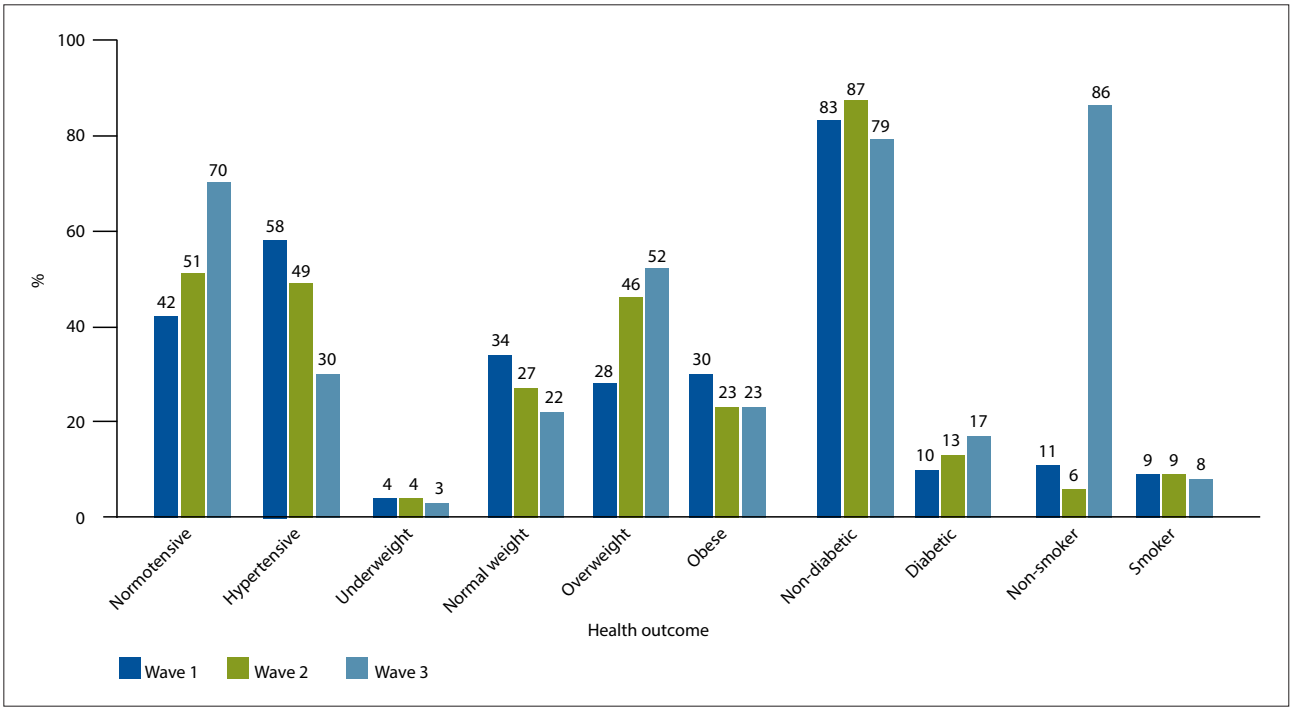

Fig. 2. Changes in health outcome trends.

to increase with age. A study conducted in Ghana showed that there was a 53.72% hypertension prevalence rate among older adults, and the trend increased with increasing age.[19] A study in China showed a continuous rise in SBP from age 35 to 79 years, and a concurrent early increase in the risk of high DBP after age 50 - 65 years.[20] The high SBP risk progresses more rapidly in the early lifetime in women, compared with the lifetime thereafter.[20] Older adults are more likely to develop hypertension due to age-related physiological changes, such as increased arterial stiffness and endothelial dysfunction.[21] These factors contribute to elevated blood pressure by impairing the ability of blood vessels to regulate blood flow.[21] These results underscore the importance of implementing age-targeted interventions, including regular health screenings, lifestyle modifications and medication management, to prevent and manage hypertension in older populations.

High BMI (overweight/obese) was a significant predictor of hypertension in wave 2 (p=0.014), which is consistent with existing literature. A study showed that there is a linear correlation between body weight and BMI with blood pressure, where an increase in body weight of 1 kg increased SBP by 0.725 mmHg and DBP by 0.318 mmHg. In addition, an increase in BMI of 1 kg/m^2 was followed by an increase in SBP and DBP of 1.6 mmHg and 0.834 mmHg, respectively.[22] Obesity is a well-known risk factor for hypertension,

Table 2. Changes in hypertension status

Hypertension status	Wave 1 - wave 2*	Proportion, %	Wave 2 - wave 3†	Proportion, %
Consistently hypertensive	1 132	30.5	649	17.5
Consistently normotensive	873	23.6	1 428	38.5
Hypertensive to normotensive	1 018	27.5	1 167	31.5
Normotensive to hypertensive	684	18.4	463	12.5
Total	3 707	100	3 707	100

*Wave 1 - wave 2: Pearson $\chi^2(3)=3.7e+03$ Pr=0.000.
†Wave 2 - wave 3: Pearson $\chi^2(3)=3.7e+03$ Pr=0.000.

likely due to increased vascular resistance and sympathetic nervous system activity.[23] Studies suggest that even modest weight loss can significantly lower blood pressure, highlighting the importance of maintaining a healthy weight through lifestyle intervention.[24]

High alcohol consumption frequency significantly increased the odds of hypertension in wave 3 (p=0.009). Previous studies demonstrated that high alcohol frequency (≥3 standard drinks per day) is associated with and predictive of hypertension; a reduction in alcohol frequency is associated with a significant dose-dependent lowering of mean SBP and DBP.[25] Excessive alcohol intake can elevate blood pressure by affecting vascular tone and increasing sympathetic nervous system activity. High-dose alcohol ≥13 hours after consumption has been found to increase SBP by 3.7 mmHg, DBP by 2.4 mmHg, and heart rate (HR) by 2.7 bpm (moderate certainty evidence for all).[26] Studies have shown that there is a causal association between high alcohol frequency and risk of hypertension, especially an alcohol intake >12 g/d. They are consistent with recommendations to avoid or limit alcohol intake.[27] Given the cultural acceptance of alcohol use in many rural communities, addressing alcohol consumption is crucial for reducing the burden of hypertension.

Increased fruit consumption lowered odds of hypertension, consistent with previous studies. A systematic review indicated that a high intake of fruit and vegetables, particularly fruit, was associated with a reduced risk of hypertension.[28] In our study, vegetable consumption was significant within the study population. There is a need for targeted public health intervention to promote healthier dietary habits for both fruit and vegetable consumption.

Individuals with no formal education had higher odds of hypertension (p=0.026). This is consistent with current studies demonstrating that lower education levels are associated with poorer health outcomes and limited access to health information.[29] A nationwide longitudinal study conducted in China on the association of education status with the risk of hypertension and its control revealed that individuals with higher education levels exhibited a significantly lower hypertension prevalence and decreased SBP and DBP.[29] A study conducted in the USA also found similar results among older US adults: those with less education were more likely to experience hypertension and uncontrolled BP than those with more schooling.[30] A study conducted in SA also found that a high level of education was inversely related to the odds of hypertension prevalence.[31]

Employed individuals had lower odds of hypertension within the study population (p=0.020). Employment may present a protective effect through increased physical activity, better access to healthcare resources and social support.[32] Previous studies found that employment was protective of hypertension, with 70% lower odds of hypertension among those employed compared with those not in any form of employment.[32] However, work-related stress can contribute to hypertension. A 22-year follow-up study of 12 080 adults aged 18 - 65 years who participated in the China Health and Nutrition Survey between 1989 and 2011 revealed the relationship between working hours and hypertension. Specifically, working overtime was identified as a significant occupational risk factor for adults, while shorter working hours were associated with an increased risk of hypertension among non-manual workers.[33]

Diabetes was not significant within the study population. However, diabetes shares common risk factors with hypertension, such as insulin resistance and obesity, which contribute to their interconnectedness.[34] A study has shown that the prevalence of hypertension among type 2 diabetes patients was 59.5%.[35] Stage 1 hypertension was the most common (30.95%).[35] Diabetic individuals' odds of hypertension were highest among the age group 50 - 60 years, with aOR=2.5.[35] Patients with longer duration of type 2 diabetes had aOR=1.16, and patients with poor glycaemic control had aOR=3.0.[35] A study conducted in Ethiopia found that hypertension was prevalent in over half of diabetic patients. The relationship between hypertension and diabetes highlights the need for integrated care strategies to manage both conditions effectively, particularly in rural areas.[36]

Although smoking was not significant within the study population, it is a well-established associated factor for hypertension and cardiovascular disease. A study conducted in China showed that heavy smokers of machine-rolled cigarettes had an elevated hypertension risk compared with non-smokers (HR 1.50, 95% CI 1.05 - 2.16).[37] The interaction effects of heavy smoking-heavy drinking patterns increased future hypertension risk, with an adjusted HR of 2.58 (95% CI 1.06 - 6.33).[37]

The present study highlights the need for comprehensive hypertension prevention and management strategies in rural SA, to expand hypertension screening programmes, promote healthy diets, physical activity and weight loss management, implement community-based education on the risks of excessive alcohol consumption and improve literacy and health knowledge during clinic visits.

Study limitations

The study analysed secondary data, which has its limitations. These include having no control over data collection. Other significant diseases, specifically chronic kidney disease, were not included as captured variables, as they are not present in the HAALSI dataset. This omission affects the comprehensiveness of the analysis regarding hypertension risk factors. There is an absence of data on secondary causes of hypertension within the HAALSI datasets, such as secondary hypertension, which can be caused by conditions such as hypo-/hyperthyroidism, coarctation of the aorta, hyperparathyroidism, vasculitis, autoimmune diseases, pheochromocytoma, Cushing's disease/syndrome, renal artery stenosis, glomerulonephritis, nephrotic syndrome and drug-induced hypertension (e.g. due to steroids or sympathomimetics). The exclusion of these variables from our analysis means that our findings are primarily focused on primary hypertension, and do not fully capture the complexity of

Table 3. Multivariable generalised estimating equation (GEE) analysis

Characteristic	Wave	Hypertension prevalence, *n** (%)	Bivariate analysis (χ^2)			Multivariable analysis (GEE)		
			OR	95% CI	*p*-value	aOR	95% CI	*p*-value
Age group								
1 (40 - 49)	1	432 (12)	Ref	-	-	Ref	-	-
1	2	201 (5.4)	0.72	0.59 - 0.87	**0.001**	0.64	0.48 - 0.84	**0.014**
1	3	77 (2.1)	0.94	0.72 - 1.24	0.698	-	-	-
2 (50 - 59)	1	667 (18)	Ref	-	-	Ref	-	-
2	2	474 (13)	1.00	0 .86 - 1.15	0.983	-	-	-
2	3	238 (6.4)	0.80	0.68 - 0.95	**0.011**	-	-	-
3 (60 - 69)	1	585 (16)	Ref	-	-	Ref	-	-
3	2	457 (12)	1.08	0.94 - 1.25	0.249	-	-	-
3	3	345 (9)	1.16	0.99 - 1.35	**0.051**	-	-	-
4 (70 - 79)	1	319 (8)	Ref	-	-	Ref	-	-
4	2	379 (1.13)	1.13	0.96 - 1.33	**0.129**	-	-	-
4	3	262 (10)	1.05	0.89 - 1.25	0.515	-	-	-
5 (≥80)	1	146 (4)	Ref (**0.011**)	-	-	Ref	-	-
5	2	214 (6)	0.99	0.81 - 1.21	0.956	-	-	-
5	3	184 (5)	1.00	0.83 - 1.21	0.945	-	-	-
Salt, excessive use	1	37 (1)	Ref (**0.24**)	-	-	Ref	-	-
	2	38 (1.01)	1.03	0.88 - 1.21	0.831	-	-	-
	3	37 (1)	1.00	0.83 - 120	0.939	-	-	-
Fruits	1	165 (4.5)	Ref	-	-	Ref	-	-
	2	139(3.7)	0.87	0.71 - 1.08	**0.108**	-	-	-
	3	74 (2)	0.96	0.76 - 1.22	**0.000**	0.95	0.91 - 0.99	0.037
Vegetables	1	118 (3)	Ref	-	-	Ref	-	-
	2	118 (3)	0.96	0.78 - 1.19	**0.112**	-	-	-
	3	39 (1)	1.03	0.82 - 1.29	**0.000**	-	-	-
Soft drink	1	0 (0)	Ref	-	-	Ref	-	-
	2	1 (0.03)	0.97	0.81 - 1.16	**0.073**	-	-	-
	3	1 (0.03)	1.02	0.84 - 1.25	0.392	-	-	-
Employed	1	580 (16)	Ref	-	-	Ref	-	-
	2	343(9)	0.87	0.73 - 1.04	0.458	0.82	0.69 - 0.96	0.020
	3	93 (3)	0.32	1.03 - 1.69	**0.026**	-	-	-
Alcohol frequency	1	74 (2)	Ref	-	-	Ref	-	-
	2	72 (1.9)	1.10	0.63 - 1.93	0.491	-	-	-
	3	46 (1.2)	0.82	0.49 - 1.36	**0.171**	1.19	1.04 - 1.37	0.009
Alcohol quantity	1	21 (0.6)	Ref	-	-	Ref	-	-
	2	17 (0.5)	0.77	0.32 - 1.90	0.788	-	-	-
	3	22 (0.6)	0.97	0.70 - 1.33	**0.028**	-	-	-
Smoking (yes)	1	198 (5)	Ref	-	-	Ref	-	-
	2	156 (4)	0.73	0.52 - 1.03	**0.201**	-	-	-
	3	91 (2)	1.04	0.80 - 1.35	**0.000**	-	-	-
Diabetes (yes)	1	206 (6)	Ref	-		Ref	-	-
	2	252 (7)	1.20	0.99 - 1.45	**0.065**	-	-	-
	3	227 (6.1)	1.37	1.14 - 1.64	**0.000**	-	-	-
BMI category (overweight/obese)	1	1 286 (35)	Ref	-	-	Ref	-	-
	2	1 251 (25)	0.95	0.81 - 1.12	**0.000**	1.11	1.02 - 1.21	**0.014**
	3	782/3 703 (21)	0.57	0.47 - 0.68	**0.000**	-	-	-
No formal education	1	922 (6)	Ref	-	-	Ref	-	-
	2	764 (21)	0.80	0.63 - 1.02	**0.218**	1.07	1.00 - 1.14	**0.026**
	3	488 (13)	0.80	0.63 - 1.02	0.859	-	-	-

P<0.05. Significant results are marked in bold.
OR = odds ratio from the bivariate analysis; CI = confidence interval; aOR= adjusted odds ratio; Ref = reference category.
**n*/3 707, unless otherwise indicated.

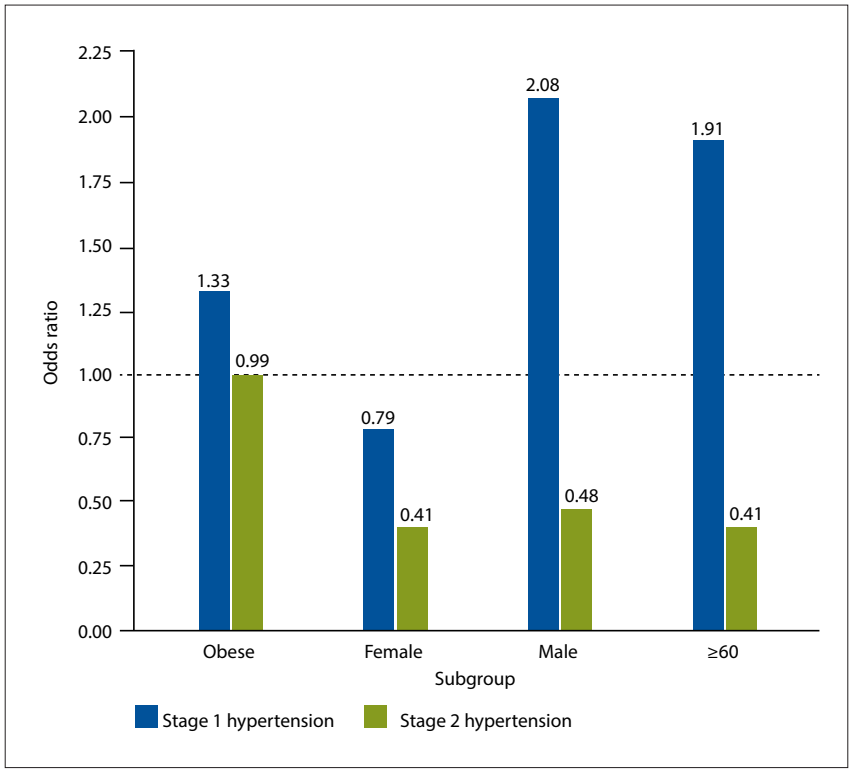

Fig. 3. Odds ratios for stage 1 and stage 2 hypertension by subgroup.

hypertension in the studied population. This limitation could lead to an underestimation or misattribution of the causes of elevated blood pressure, particularly in cases where secondary hypertension is present but not diagnosed or recorded in the datasets.

Conclusion

The study analysed temporal trends of hypertension prevalence and its associated risk factors among adults aged ≥40 years in Agincourt HDSS, Mpumalanga Province, SA. The study revealed that the prevalence of hypertension decreased from 58% to 30% between waves 1 and 3, with a notable proportion of individuals transitioning from hypertensive to normotensive over time. Key predictors of hypertension included high BMI, frequent alcohol consumption and having no formal education, while protective factors included younger age group, employment and fruit consumption. In the sensitivity analysis, males and age ≥60 years had increased odds of stage 1 hypertension. Obese individuals had increased odds of both stage 1 and stage 2 hypertension. Future studies should focus on increasing access to hypertension screenings and promoting lifestyle modifications in rural areas, to further reduce the burden of hypertension as the leading cause of cardiovascular disease.

Data availability. The data used in this study are publicly available and can be accessed from the HAALSI dataset at https://haalsi.org.

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1. World Health Organization. Hypertension. Geneva: WHO, 2023. https://www.who.int/health-topics/hypertension (accessed10 September 2023).
2. Hegde S, Ahmed I, Aeddula NR. Secondary hypertension. StatPearls. Treasure Island (FL): StatPearls Publishing, 2024. https://www.ncbi.nlm.nih.gov/books/NBK544305/ (accessed 20 October 2024).
3. Oparil S, Acelajado MC, Bakris GL, et al. Hypertension. Nat Rev Dis Primers 2018;4:18014. https://doi.org/10.1038/nrdp.2018.14
4. Mills KT, Stefanescu A, He J. The global epidemiology of hypertension. Nat Rev Nephrol 2020;16(4):223-237. https://doi.org/10.1038/s41581-019-0244-2
5. American Heart Association. Understanding blood pressure readings. AHA, 14 August 2025. https://www.heart.org/en/health-topics/high-blood-pressure/understanding-blood-pressure-readings (accessed 30 August 2024).
6. InformedHealth.org. In brief: How is blood pressure measured? Cologne: Institute for Quality and Efficiency in Health Care (IQWiG); 2006. https://www.ncbi.nlm.nih.gov/books/NBK279251/ (accessed 3 July 2024).
7. Kunnas T, Nikkari ST. Family history of hypertension enhances age-dependent rise in blood pressure, a 15-year follow-up: The Tampere adult population cardiovascular risk study. Medicine 2023;102(39):e35366. https://doi.org/10.1097/MD.0000000000035366
8. Moloro AH, Seid AA, Jaleta FY. A systematic review and meta-analysis protocol on hypertension prevalence and associated factors among bank workers in Africa. SAGE Open Med 2023;11:20503121231172001. http://doi.org/10.1177/20503121231172001
9. World Health Organization. World Health Statistics 2024. Monitoring health SDGs, Sustainable Development Goals. Geneva: WHO, 2024. https://iris.who.int/bitstream/handle/10665/376869/9789240094703-eng.pdf (accessed 7 November 2024).
10. Reddy SP, Mbewu AD, Williams DR, et al. Race, geographical location and other risk factors for hypertension: South African National Health and Nutrition Examination Survey 2011/12. SSM Popul Health 2021;16:100986. https://doi.org/10.1016/j.ssmph.2021.100986
11. Kandala N-B, Nnanatu CC, Dukhi N, Sewpaul R, Davids A, Reddy SP. Mapping the burden of hypertension in South Africa: A comparative analysis of the national 2012 SANHANES and the 2016 Demographic and Health Survey. Int J Environ Res Public Health 2021;18(10):5445. https://doi.org/0.3390/ijerph18105445
12. Kuehn BM. Hypertension rates in rural areas outpace those in urban locales. JAMA 2020;323(24):2454. https://doi.org/10.1001/jama.2020.9382
13. Gómez-Olivé FX, Montana L, Wagner RG, et al. Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI). Int J Epidemiol 2018;47(3):689-690. https://doi.org/10.1093/ije/dyx247
14. Statistics South Africa. Mortality and causes of death in South Africa, 2018: Findings from death notification. Pretoria: Stats SA, 2020. https://www.statssa.gov.za/publications/Report-03-08-01/Report-03-08-012018.pdf (accessed 22 October 2024).
15. National Department of Health, South Africa. National Strategic Plan for the Prevention and Control of Non-Communicable Diseases 2022–2027. Pretoria: NDoH, 2022. https://bhekisisa.org/wp-content/uploads/2022/06/NCDs-NSP-SA-2022-2027-1.pdf (accessed 2024 October 22).
16. United Nations. The Sustainable Development Goals Report 2023. New York: UN, 2023. https://unstats.un.org/sdgs/report/2023/ (accessed 15 November 2025).
17. University of the Witwatersrand. Agincourt. Johannesburg: University of the Witwatersrand, 2024. https://www.wits.ac.za/agincourt/ (accessed 5 June 2024).
18. Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. Source Code Biol Med 2008;3(1):17. https://doi.org/10.1186/1751-0473-3-17
19. Dai B, Addai-Dansoh S, Nutakor JA, et al. The prevalence of hypertension and its associated risk factors among older adults in Ghana. Front Cardiovasc Med 2022;9:990616. https://doi.org/10.3389/fcvm.2022.990616
20. Cheng W, Du Y, Zhang Q, et al. Age-related changes in the risk of high blood pressure. Front Cardiovasc Med 2022;9(15):939103. https://doi.org/10.3389/fcvm.2022.939103
21. Singh JN, Nguyen T, Kerndt CC, et al. Physiology, blood pressure age related changes. StatPearls. Treasure Island (FL): StatPearls Publishing, 2024. https://www.ncbi.nlm.nih.gov/books/NBK537297/ (accessed 19 November 2024).
22. Yusni Y, Rahman S, Naufal I. Positive correlation between body weight and body mass index with blood pressure in young adults. Narra J 2024;4(1):e533. https://doi.org/10.52225/narra.v4i1.533
23. Hall JE, do Carmo JM, da Silva AA, Wang Z, Hall ME. Obesity-induced hypertension: Interaction of neurohumoral and renal mechanisms. Circ Res 2015;116(6):991-1006. https://doi.org/10.1161/CIRCRESAHA.116.305697
24. Gilardini L, Redaelli G, Croci M, Conti A, Pasqualinotto L, Invitti C. Effect of a modest weight loss in normalizing blood pressure in obese subjects on antihypertensive drugs. Obes Facts 2016;9(4):251-258. https://doi.org/10.1159/000445504
25. Miller PM, Anton RF, Egan BM, Basile J, Nguyen SA. Excessive alcohol consumption and hypertension: Clinical implications of current research. J Clin Hypertens 2005;7(6):346-351. https://doi.org/10.1111/j.1524-6175.2004.04463.x
26. Tasnim S, Tang C, Musini VM, Wright JM. Effect of alcohol on blood pressure. Cochrane Database Syst Rev 2020;7(7):CD012787. https://doi.org/10.1002/14651858.CD012787.pub2
27. Cecchini M, Filippini T, Whelton PK, et al. Alcohol intake and risk of hypertension: A systematic review and dose-response meta-analysis of nonexperimental cohort studies. Hypertension 2024;81(8):1701-1715. https://doi.org/10.1161/HYPERTENSIONAHA.124.22703

28. Madsen H, Sen A, Aune D. Fruit and vegetable consumption and the risk of hypertension: A systematic review and meta-analysis of prospective studies. Eur J Nutr 2023;62(5):1941-1955. https://doi.org/10.1007/s00394-023-03145-5
29. Sun K, Lin D, Li M, et al. Association of education levels with the risk of hypertension and hypertension control: A nationwide cohort study in Chinese adults. J Epidemiol Community Health 2022;76(5):451-457. https://doi.org/10.1136/jech-2021-217006
30. Zacher M. Educational disparities in hypertension prevalence and blood pressure percentiles in the Health and Retirement Study. J Gerontol B Psychol Sci Soc Sci 2023;78(9):1535-1544. https://doi.org/10.1093/geronb/gbad084
31. Madela S, Harriman N, Sewpaul R, et al. Individual and area-level socioeconomic correlates of hypertension prevalence, awareness, treatment, and control in uMgungundlovu, KwaZulu-Natal, South Africa. BMC Public Health 2023;23:417. https://doi.org/10.1186/s12889-023-15247-0
32. Twinamasiko B, Lukenge E, Nabawanga S, et al. Sedentary lifestyle and hypertension in a periurban area of Mbarara, South Western Uganda: A population-based cross-sectional survey. Int J Hypertens 2018;2018:8253948. https://doi.org/10.1155/2018/8253948
33. Cheng H, Gu X, He Z, Yang Y. Dose-response relationship between working hours and hypertension: A 22-year follow-up study. Medicine 2021;100(16):e25629. https://doi.org/10.1097/MD.0000000000025629
34. Yashi K, Daley SF. Obesity and Type 2 Diabetes. StatPearls. Treasure Island (FL): StatPearls Publishing, 2024. https://www.ncbi.nlm.nih.gov/books/NBK592412/ (accessed 19 November 2024).
35. Akalu Y, Belsti Y. Hypertension and its associated factors among type 2 diabetes mellitus patients at Debre Tabor General Hospital, Northwest Ethiopia. Diabetes Metab Syndr Obes 2020;13:1621-1631. https://doi.org/10.2147/DMSO.S254537
36. Belew MA, Abate TW, Berhie AY, et al. Determinants of hypertension among diabetes patients attending selected comprehensive specialised hospitals of the Amhara Region, Ethiopia: An unmatched case-control study. PLoS ONE 2022;17(12):e0279245. https://doi.org/10.1371/journal.pone.0279245
37. Gao N, Liu T, Wang Y, et al. Assessing the association between smoking and hypertension: Smoking status, type of tobacco products, and interaction with alcohol consumption. Front Cardiovasc Med 2023;10:1027988. https://doi.org/10.3389/fcvm.2023.1027988

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