Geographical influence on the distribution of the prevalence of hypertension in South Africa: a multilevel analysis

Muchiri E Wandai, Shane A Norris, Jens Aagaard-Hansen, Samuel OM Manda

Abstract

Background: As a response to the growing burden of non-communicable diseases, the South African government has set targets to reduce the prevalence of people with raised blood pressure, through lifestyle changes and medication, by 20% by the year 2020. It has also recognised that the prevalence varies at local administrative level. The study aim was to determine the geographical variation by district of the prevalence of hypertension among South African adults aged 15 years and above.

Methods: Data from all five waves of the National income Dynamics Study, a panel survey, were used for estimation by both design-based and multilevel analysis methods. In the multilevel analysis, a three-level hierarchy was used with panel participants in the first level, repeated measurements on patients in the second level, and districts in the third level.

Results: After accounting for demographic, behavioural, socio-economic and environmental factors, significant variation remained in the prevalence of hypertension at the district level. Districts with higher-than-average prevalence were found mostly in the south-western part of the country, while those with a prevalence below average were found in the northern area. Age, body mass index and race were the individual factors found to have a strong effect on hypertension prevalence for this sample.

Conclusions: There were significant differences in hypertension prevalence between districts and therefore the method of analysis and the results could be useful for more targeted preventative and control programmes.

Keywords: hypertension prevalence, district variability, random effects, multilevel analysis

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Hypertension is a major risk factor and consistent predictor for cardiovascular diseases, such as coronary heart disease, stroke, transient ischaemic attack and congestive heart failure.[1,2] A study based on data from the 36-year follow-up Framingham study pointed out the urgent need for primary prevention of hypertension by addressing associated risk factors through weight control, exercise and reduced salt and alcohol intake.[3]

In 2015, global age-standardised prevalence of raised blood pressure was estimated to be 24.1% (21.4–27.1) of men and 20.1% (17.8–22.5) of women. The number of adults with raised blood pressure has increased from 594 million in 1975 to 1.13 billion in 2015, with the increase largely in low- and middle-income countries (LMICs).[4] According to the 2012 South African National Health and Nutritional and Health Examination Survey (SANHANES), the prevalence of hypertension was approximately 26.0%,[5] and the 2016 Demographic Health Survey estimated the prevalence to be 46.0 and 44.0% for women and men, respectively.[6] A number of studies have reported higher-than-global average prevalence in LMICs,[7-9] and this has been attributed to non-compliance with treatment, urbanisation, population ageing and behavioural risk factors, including tobacco and alcohol use, poor diet and physical inactivity.[7,9,10]

In 2013, the South African National Department of Health developed a strategic plan for the prevention and control of non-communicable diseases, which targets reducing the prevalence of people with raised blood pressure by 20% by the year 2020, through lifestyle change and medication.[11] While prevalence has been estimated at both provincial and national levels, little is known on the prevalence of hypertension at levels below the province due to limited data that can reliably be used for estimation.

In South Africa, existing surveillance and estimation of hypertension and other non-communicable disease (NCD)-related risk factors are overwhelmingly focused at the first (national) or second (provincial) level geographies,[5,12-14] but gaining a better understanding of variations at the finer resolutions (district level in particular) could be important in decision making for improving the effectiveness and efficiency in the response to hypertension.

While efforts have been made to estimate hypertension prevalence at the district level, the method used has fallen short as it does not account for factors that are known to be associated with prevalence. In one study, district-based prevalence of cardiovascular co-morbidities, including hypertension, were estimated using an outdated data set (1998 South African Demographic Health Survey).[15] National prevalence of disease can conceal important differences in prevalence in sub-national areas.[16] In most high-income countries where data are available to finer geographies such as counties, NCD-related studies have shown substantial heterogeneity in the prevalence of these diseases and associated risk factors between sub-regions within a country.[17-19]

The aim of this study was therefore to profile the variations in hypertension prevalence between districts in South Africa after controlling for the individual's demographic, social, economic, behavioural and environmental variables.

Methods

The 2008, 2010/11, 2012, 2014/15 and 2017 samples for adults aged 15 years and above from the National income Dynamics Study (NiDS) panel survey were used in the study. The survey provides a large nationally representative sample that is stratified by the country's 52 districts.

The target population was adult (15+ years) individuals in private households and residents in workers' hostels, convents and monasteries, but excluded other living quarters such as students' hostels, old-age homes, hospitals, prisons and military barracks. The sampling technique employed in the panel study is exhaustively discussed elsewhere.[20] The sample retained for the study includes respondents who had at least two blood pressure (BP) measurements taken at the time of the survey.

The outcome of interest was hypertension prevalence for individuals with systolic/diastolic BP of more than 140/90 mmHg or on medication for hypertension. BP measurements for each panel were taken twice from each survey respondent. Valid BP measurements were determined according to previously applied criteria[13,21] as follows: (1) if the second systolic or diastolic BP differed by more than 5 mmHg, the first BP reading was excluded; and (2) a set of BP readings (systolic and diastolic) was retained in the data set if the systolic BP was 80 mmHg or higher AND if the systolic BP was at least 15 mmHg higher than the diastolic BP level. A final systolic/diastolic blood pressure was calculated as the average of the valid BP measurements (Table 1).

Several risk factors known to be associated with hypertension and recorded in the NiDS data were adjusted for in estimating the prevalence of hypertension, using multilevel logistic regression. Important factors at the individual level were (1) demographic factors: age, gender and race (self-identification as African, Coloured, white, Asian/Indian); (2) biological factors: specifically body mass index (BMI); (3) behavioural factors: alcohol use (never used and past/current user), smoking status (never and past/current) and physical exercise (none or some exercise); (4) social and economic factors: education level (≤ primary school, high school, and post high school), employment status (employed, unemployed or economically inactive), medical cover status (membership subscription to a registered medical aid provider), residency type (urban and traditional/farms), and income tertile calculated from equivalised per-capita household income (household income divided by square root of number of people in household); and (5) one environmental factor: the season (summer, autumn, winter and spring) when the BP measurements were taken.

Subjects self-identifying as whites or Indians/Asians were combined in the analysis as they had relatively smaller sample sizes. The alcohol use variable was not available for wave 5 (2017), and so the last observed status (from previous waves) was used, or indicated as unknown if the subject was not in previous waves.

Ethics approval was granted by the Human Research and Ethics Committee of the University of the Witwatersrand, Johannesburg, South Africa

Statistical analysis

The prevalence of hypertension was estimated using the following two statistical methods reporting results at the district level.

Design-based estimates used the survey's post-stratification weights. This first step of the analysis was to estimate the prevalence of hypertension nationally and by the levels of each explanatory variable on univariate basis, followed by the estimation of the prevalence by districts.

A three-level analysis model was used where periodic (survey waves or the repeated measurements) hypertension statuses (first level) are nested in individual respondents (second level), nested within districts (third level). The risk factors listed above were adjusted for in the model.

- Level-specific distribution of hypertension variance. This step aimed at estimating the distribution of the hypertension prevalence variance between the three levels, and the proportion of variance explained by the individual-level demographic, behavioural and socio-economic risk factors. This involved first fitting a multilevel model without the covariates (a null model), which allowed partitioning the variance between the hierarchical levels. This was followed by constructing a full model that adjusted for the risk factors (covariates) stated above. The variance structure was described by the variance partition coefficient (VPC) and the level-specific change in variance ($\Delta\sigma^2$). The VPC measures the proportion of variance explained by each level within the model, and the $\Delta\sigma^2$ measures the proportion of change in variance for each level between the null and the adjusted model. Together, these two measures describe how much of the variation is explained by the variables included in the model.
- Association of hypertension prevalence with individual-level risk factors. Using the fully adjusted model, odds ratios (OR) and *p*-values were calculated for each risk factor in the model.
- Estimation of adjusted hypertension prevalence at the district units involved using the predicted individual probability for hypertension in estimating the prevalence at district level. The estimated prevalences and 95% confidence intervals (CI) were graphically presented to profile districts. This procedure allowed a visualisation of which units were significantly different from the national prevalence. Further analysis was

Table 1. Sample by wave for participants 15 years and above

Wave	*Valid hypertension data*	*Total sample*	*Percentage valid*
2008	14 135	18 617	75.9
2010/11	15 128	21 943	68.9
2012	18 393	25 228	72.9
2014/15	22 526	28 460	79.1
2017	23 605	32 123	73.5
Total	93 787	126 371	74.2

done allowing for hypertension prevalence to vary by age and BMI at the geographic (district) level. This analysis was used to graphically identify units with relatively steeper slopes by age and BMI.

All analyses were performed using Stata version 15. For design-based prevalence estimate, the 'svy: tab' command for two-way tabulation was used, while the mixed-effect logit (melogit) command was used for multilevel analysis.

Results

Design-based (unadjusted) prevalence of hypertension: the univariate (weighted) analysis (Table 2) shows a decreased trend in hypertension prevalence, except for a slight increase in the 2012 period. On a period-by-period basis, the prevalence of hypertension in females was higher than that of males. Age, BMI status and educational level had the highest differentials, with those relatively older (40+ years) having a prevalence that was about four times that of the younger adults (< 40 years), and those whose BMI was 25 kg/m^2 or above (overweight or obese) having a prevalence almost double that of those with a BMI less than 25 kg/m^2 (normal weight).

Subjects who had primary-level education or no education had a significantly higher prevalence compared to those with relatively higher educational levels, and those who were unemployed had lower prevalence compared with the employed and economically

Table 2. Percentage (95% CI) of hypertension prevalence in South Africa by covariate and period

Characteristic	*2008*	*2010/11*	*2012*	*2014/15*	*2017*	*Average (all)*
Gender						
Female	33.7 (31.7–35.7)	31.9 (30.2–33.7)	33.5 (31.8–35.2)	29.4 (27.8–31.0)	28.5 (27.1–29.9)	31.2 (30.1–32.4)
Male	28.7 (26.5–30.9)	27.8 (25.5–30.2)	30.4 (28.0–32.9)	26.8 (24.7–28.9)	27.3 (25.6–29.1)	28.1 (26.5–29.8)
Age group						
≤ 40 years	16.4 (14.8–18.1)	16.0 (14.6–17.5)	17.3 (15.8–18.9)	13.8 (12.4–15.4)	13.9 (12.8–15.0)	15.3 (14.4–16.3)
> 40 years	58.0 (55.5–60.4)	55.0 (52.6–57.3)	57.2 (54.8–59.5)	53.0 (51.0–55.0)	52.7 (50.6–54.7)	55.0 (53.5–56.4)
Race						
African	29.2 (27.5–30.9)	28.2 (26.8–29.6)	30.0 (28.3–31.7)	25.6 (24.4–26.9)	25.4 (24.3–26.6)	27.5 (26.5–28.5)
Mixed race	41.7 (37.4–46.1)	41.1 (35.1–47.3)	40.2 (34.7–45.9)	39.3 (35.8–42.8)	38.3 (34.3–42.5)	39.9 (36.2–43.7)
Asian/Caucasian	40.6 (35.8–45.7)	35.7 (29.0–43.1)	40.1 (35.1–45.4)	36.5 (29.5–44.2)	39.9 (35.7–44.3)	38.6 (34.7–42.6)
Residency						
Urban	33.4 (31.2–35.6)	32.6 (30.6–34.7)	33.0 (30.8–35.2)	29.5 (27.5–31.6)	29.3 (27.8–30.9)	31.3 (29.9–32.7)
Traditional/farms	28.8 (26.8–30.9)	26.2 (24.6–27.9)	30.6 (28.6–32.7)	25.9 (24.5–27.3)	25.2 (23.8–26.7)	27.3 (26.2–28.5)
Education level						
≤ Primary	46.1 (43.4–48.8)	45.3 (43.1–47.6)	48.9 (46.3–51.4)	48.1 (45.9–50.3)	47.9 (45.5–50.4)	47.2 (45.4–49.0)
High school	24.7 (22.6–26.8)	23.4 (21.6–25.3)	25.6 (23.6–27.8)	21.5 (19.7–23.4)	21.5 (20.1–23.0)	23.2 (21.8–24.7)
Certificate/diploma/bachelors'+	28.1 (24.6–31.9)	28.3 (24.1–32.9)	31.0 (27.8–34.5)	26.8 (24.0–29.9)	29.4 (27.1–31.8)	28.7 (26.8–30.7)
Income tertile						
Low	29.1 (27.3–31.0)	27.3 (25.7–28.9)	28.7 (26.5–30.9)	24.4 (22.5–26.4)	23.5 (20.6–26.7)	27.3 (26.1–28.5)
Medium	33.3 (30.7–36.0)	31.8 (29.4–34.3)	32.4 (30.4–34.4)	27.7 (25.9–29.6)	26.1 (24.6–27.6)	29.9 (28.6–31.2)
High	34.3 (31.3–37.4)	32.0 (29.1–35.0)	34.4 (31.8–37.1)	29.8 (27.7–32.0)	29.8 (28.3–31.3)	31.4 (29.9–32.9)
Employment status						
Employed	32.8 (30.6–35.1)	31.4 (28.8–34.2)	32.9 (30.7–35.2)	28.6 (26.6–30.7)	27.8 (26.2–29.4)	30.3 (29.0–31.8)
Unemployed	24.4 (21.8–27.1)	23.1 (19.9–26.7)	23.4 (20.6–26.5)	19.8 (16.8–23.1)	19.9 (17.4–22.7)	22.2 (20.6–23.9)
Economically inactive	33.8 (31.3–36.3)	31.2 (29.5–33.0)	34.6 (32.5–36.7)	30.3 (28.5–32.1)	30.4 (28.8–32.1)	31.9 (30.5–33.3)
Medical aid						
Yes	35.7 (31.3–40.4)	31.7 (26.7–37.2)	36.8 (32.7–41.0)	33.2 (28.9–37.9)	33.3 (30.0–36.7)	29.0 (28.0–30.1)
No	30.8 (29.2–32.5)	29.7 (28.3–31.2)	31.3 (29.7–32.9)	27.2 (25.9–28.6)	26.9 (25.7–28.2)	34.1 (31.4–36.9)
Body mass index						
Below overweight	21.5 (19.7–23.3)	20.1 (18.5–21.7)	21.2 (19.4–23.1)	16.8 (15.4–18.2)	17.1 (15.8–18.5)	19.1 (18.1–20.2)
Overweight/obese	40.7 (38.5–42.9)	38.7 (36.7–40.8)	41.9 (39.7–44.0)	38.6 (36.6–40.7)	38.2 (36.6–39.7)	39.5 (38.2–40.9)
Exercise						
Never exercise	34.2 (32.5–36.0)	32.2 (30.5–33.9)	34.0 (32.3–35.8)	31.1 (29.5–32.6)	30.7 (29.4–32.1)	32.3 (31.3–33.4)
Some exercise	26.7 (24.0–29.5)	25.4 (22.7–28.4)	27.8 (24.9–30.8)	23.1 (20.8–25.6)	22.8 (21.1–24.5)	24.9 (23.2–26.7)
Alcohol use						
Yes	34.1 (31.5–36.9)	30.5 (27.4–33.8)	33.3 (30.7–36.0)	29.8 (27.4–32.3)	30.3 (27.7–33.0)	29.5 (28.3–30.8)
No	30.6 (28.8–32.4)	29.9 (28.3–31.5)	31.6 (29.9–33.3)	27.3 (25.9–28.9)	28.4 (27.0–29.8)	31.4 (29.7–33.2)
Unknown	–	–	–	–	23.5 (21.2–26.0)	23.5 (21.2–26.0)
Smoking status						
Never smoked	30.6 (29.0–32.3)	29.2 (27.7–30.8)	31.0 (29.3–32.7)	26.7 (25.3–28.2)	26.9 (25.7–28.1)	28.7 (27.7–29.8)
Ever smoked	33.9 (31.2–36.7)	33.2 (29.8–36.9)	35.9 (32.2–39.8)	32.3 (29.2–35.6)	30.9 (28.6–33.4)	33.1 (31.0–35.3)
Season of BP measurement						
Summer	29.3 (26.8–31.8)	24.4 (21.3–27.8)	25.3 (20.4–30.9)	25.4 (24.0–26.9)	24.7 (23.0–26.5)	26.1 (25.0–27.3)
Winter	35.8 (32.8–39.0)	31.9 (29.8–34.1)	32.9 (30.7–35.2)	32.2 (27.9–36.8)	31.3 (29.2–33.4)	32.5 (31.2–33.9)
Autumn/spring	32.2 (29.7–34.9)	28.8 (26.6–31.2)	31.6 (29.4–33.9)	30.5 (27.9–33.3)	29.0 (27.1–30.9)	30.4 (29.0–31.8)
All	31.5 (29.9–33.1)	30.0 (28.6–31.5)	32.1 (30.5–33.8)	28.2 (26.8–29.6)	27.9 (26.7–29.1)	29.8 (28.7–30.9)

inactive. The African race had a lower prevalence compared with the other races. Urban dwellers, and those who had a medical aid, or engaged in no physical exercise, or had ever smoked, or had ever used alcohol, or whose BP measurements were taken in winter had hypertension prevalences higher than their respective counterparts. Those who were higher in the income band had prevalences significantly higher than those in the lower income level.

Fig. 1 shows the unadjusted weighted hypertension prevalence and 95% CI for South African districts. The average national prevalence was 29.8% (95% CI: 28.7–30.9%: green band). Approximately eight districts showed a prevalence that was lower than that of the national level, while about 16 districts showed a prevalence that was significantly higher than that of the national level. However these estimates are imprecise as characterised by the large confidence intervals.

Except for A Nzo and OR Tambo (both in the Eastern Cape Province), the districts with a lower-than-average prevalence were found in the north-eastern provinces of Limpopo and Mpumalanga. By contrast, the districts with a higher prevalence than average were from the Western and Northern Cape provinces. In between these two extremes lay the majority of the districts whose prevalence was approximately equal to the average. These districts were mostly found in KwaZulu-Natal, Gauteng, parts of the Free State and Eastern Cape, and North West provinces.

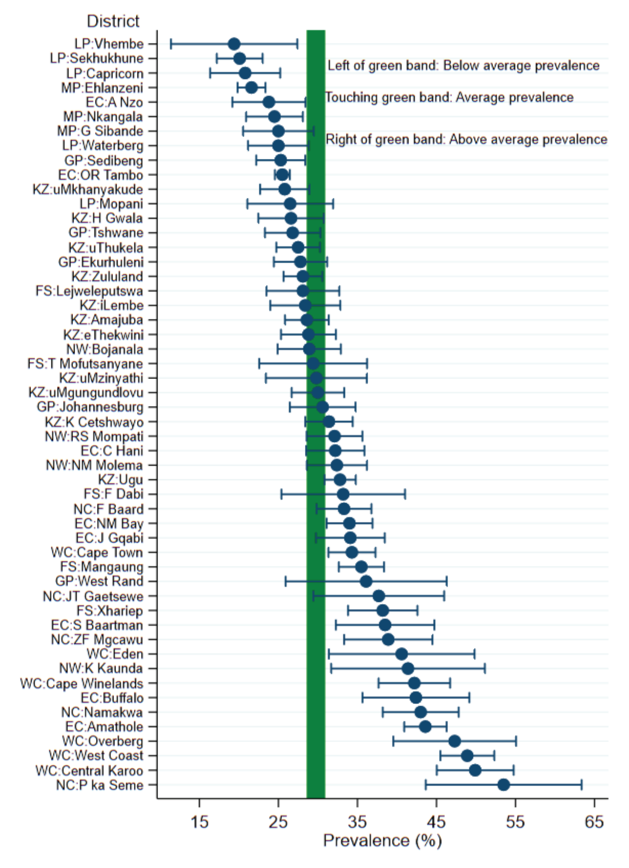

Fig. 1. Design-based hypertension prevalence rates by districts in South Africa.

Factors associated with hypertension: after accounting for other factors, the greatest effect on hypertension was shown to be basically from the demographic factors of age and race, where the OR was approximately 5.5 times more for every five years increase in age, while the Coloured and black African populations, respectively, were about 2.5 and 1.5 times more likely to be hypertensive compared with the combined races of whites and Asians.

Other factors associated with hypertension prevalence were BMI (OR = 2.29, p = 0.001 for those with BMI at least 25.0 kg/m^2), alcohol use (OR = 1.25, $p < 0.001$), season (OR = 1.33, $p < 0.001$ for winter vs autumn/spring) and residence (urban vs traditional/farm, OR = 1.12, $p \leq 0.011$). Adjusted prevalence was more likely to be lower for females compared with males and decreased with level of education. Medical aid and smoking status were not found to be significant predictors of hypertension prevalence for these samples.

Hypertension variance: Table 3 presents the distribution of hypertension variance at the individual and district levels. Most

Table 3. Fixed and random effects associated with hypertension prevalence in South Africa

Factor	*Odds ratio (95% CI)*	*p-value*
Period/year (vs 2008)		
2010/11	0.72 (0.66–0.78)	0.000
2012	0.81 (0.75–0.88)	0.000
2014/15	0.75 (0.70–0.81)	0.000
2017	0.64 (0.59–0.70)	0.000
Gender (vs male)		
Female	0.86 (0.80–0.92)	0.000
Age	1.11 (1.10–1.11)	0.000
Race (vs Asian/Caucasian)		
African	1.52 (1.30–1.78)	0.000
Mixed race	2.56 (2.13–3.07)	0.000
Residency (vs traditional/farms)		
Urban	1.12 (1.03–1.22)	0.011
Education level (vs pry and below)		
High school	0.86 (0.80–0.93)	0.000
Certificate/diploma/Bachelors'+	0.76 (0.68–0.84)	0.000
Income tertile (vs low)		
Medium	0.90 (0.85–0.96)	0.001
High	0.96 (0.89–1.03)	0.231
Employment status (vs employed)		
Unemployed	0.97 (0.90–1.04)	0.375
Economically inactive	0.93 (0.87–0.99)	0.014
Has medical aid	1.01 (0.91–1.11)	0.861
BMI (vs ≤ normal weight)		
Overweight/obesity (≥ 25 kg/m^2)	2.29 (2.16–2.42)	0.000
Physical exercise (vs no exercise)		
Some exercise	0.98 (0.92–1.03)	0.438
Alcohol use (vs never used)		
Yes	1.25 (1.17–1.33)	0.000
Unknown	1.06 (0.93–1.20)	0.384
Smoking status (vs never smoked)		
Ever smoked	1.00 (0.93–1.08)	0.920
Season (vs autumn/spring)		
Summer	0.80 (0.76–0.85)	0.000
Winter	1.33 (1.26–1.40)	0.000
Random effects		
District	0.11 (0.07–0.18)	
Repeated observations	3.32 (3.13–3.51)	

of the variance for both the unadjusted and adjusted models was at the individual level. The VPC shows the proportion of hypertension prevalence variation at the district level to be 3.5%. When adjusting for the explanatory variables, about 1.9% (3.5–1.6) of the variance in the higher level (district) is explained by the geographic distribution of demographic, behavioural, socio-economic and environmental factors (Table 4). Level 1 variance (within individuals' observation) is the fixed value 3.29 ($\pi^2/3$), which is the value assigned for a multilevel logistic regression.

Adjusted prevalence at the district level: the risk-factor adjusted prevalence estimates, unlike the unadjusted (weighted) prevalence, had narrower confidence intervals, and only about 10 districts had a prevalence approximately equal to the average prevalence. A common scenario under both estimation methods was that most of the districts with a lower-than-average prevalence were found in the northern and north-eastern part of the country, while those with a higher-than-average prevalence were mostly in the south and south-western parts of the country (the 'Cape' provinces). All the districts in the Western Cape, except Cape Town, and all the provinces in Northern Cape except Frances Baard had prevalences above average. All districts in Limpopo, Mpumalanga and Gauteng had prevalences below average (Fig 2).

Random district slopes for age and BMI: the effect of age for some districts was lower (districts whose slopes were below the red horizontal line in Fig. 3) than its overall effect. These districts included all from the Limpopo Province, and most of those in Kwa-Zulu Natal and Eastern Cape. The effect of BMI was relatively stronger in most of the districts in Limpopo, Free State, Northern Cape and Kwa-Zulu Natal, and least for most districts in the Eastern Cape.

Discussion

The purpose of this study was to analyse the degree of hypertension prevalence variation for adults aged 15 years and above at the district level before and after adjusting for risk factors associated with hypertension. According to the results of the multilevel model, factors that explained variation in hypertension status in this study were found to be consistent in certain aspects with previous research. For example, age and BMI were the two strongest factors affecting hypertension prevalence in this study, which is in agreement with other studies.[22-26]

The effect of gender on hypertension has been conflicting, with some studies showing a weak association, with females having a lower prevalence of hypertension than males,[25-27] while other studies have showed no association.[23,24,28] The results of the multivariate analysis in this study showed that females had a lower hypertension prevalence compared with males.

Table 4. Variance partition and specific-level change in variance between the null and the adjusted model

Variance component	*Null model: variance (SE)*	*Adjusted model: variance (SE)*	*Change in variance (%) (Ds^2)*
Individual	8.47 (0.224)	3.32 (0.0963)	–60.8
District	0.430 (0.082)	0.110 (0.026)	–74.4
Individual VPC (%)	69.4	49.4	
Geographic VPC (%)	3.5	1.6	

VPC: variance partition coefficient.

Alcohol use (past or current) has also been found to increase the risk of hypertension in some studies,[24,29,30] while in another study no relationship was found.[25] Smoking status, education, and employment status have also yielded conflicting results from various studies.[23,25]

The mixed race and Africans were found in the multilevel logistic regression to have increased prevalence of hypertension compared with Asians/Caucasians. This is consistent with a study done in the United States of America where there are such mixed races.[31]

Univariate analysis showed that prevalence of hypertension for those who had subscription to a medical aid provider was higher compared to those without medical aid, but multivariate analysis showed no association. This is possibly because its confounding effect was reduced by income level and education. The percentage of those subscribed to a medical aid cover increased with higher income and educational level.

The study also found seasonal effects with the odds of increased hypertension prevalence being higher in the winter months compared with summer. This is consistent with other studies that have shown cold ambient temperatures to be associated with elevated blood pressure,[32-35] and therefore the effect has also been found to be larger in winter than in summer.[36-38]

Analyses of variance at the individual and district level showed differences in the hypertension prevalence variance

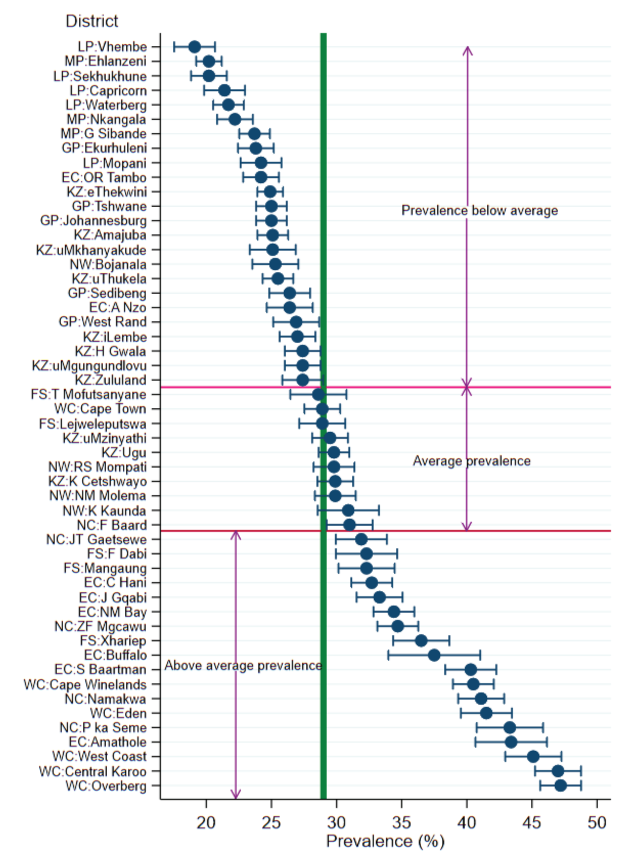

Fig. 2. Mean difference in hypertension prevalence and 95% CI for South African districts (adjusted model).

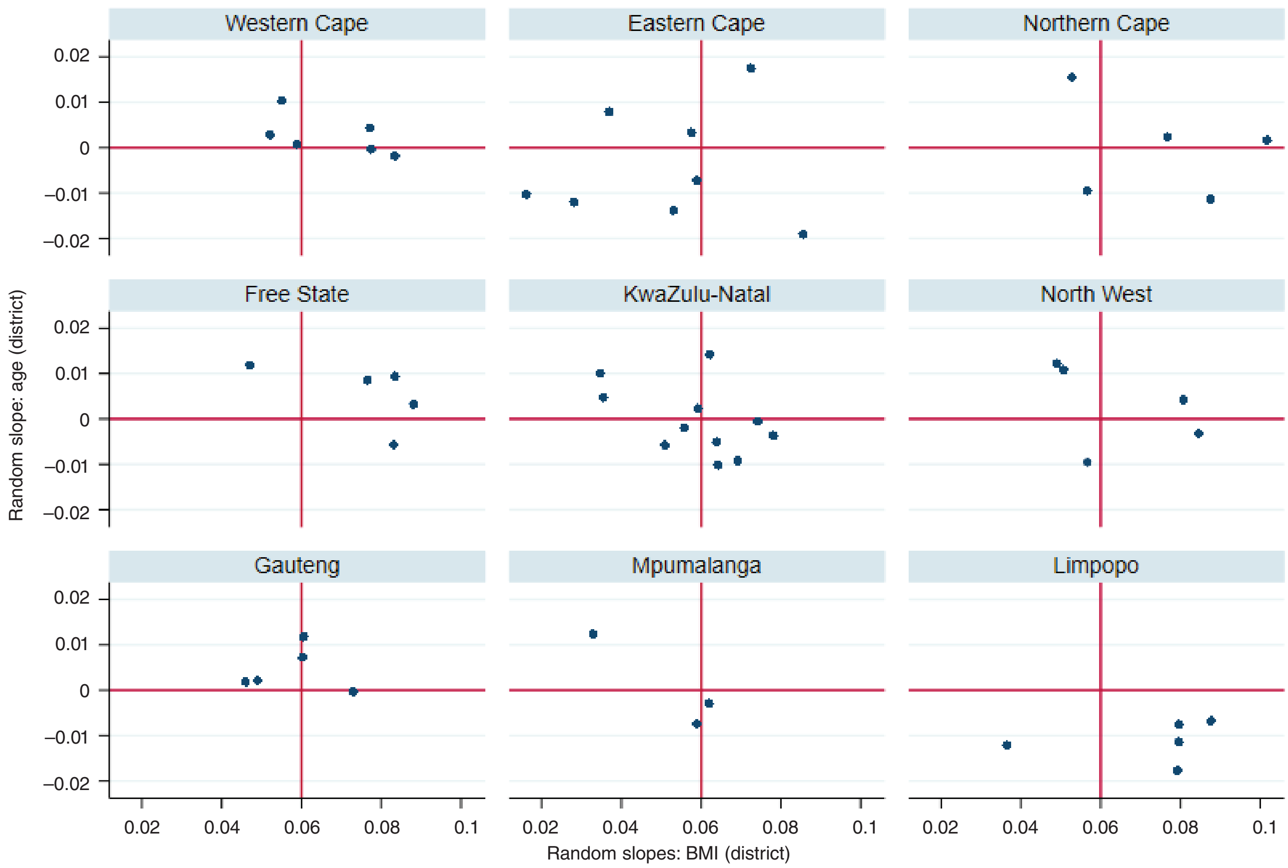

Fig. 3. Scatter plot for districts' random slopes for age and BMI.

distribution at the higher level (district), with a VPC of 3.8 and 2.1% for the null and the risk-factor-adjusted models, respectively. After adjusting for the effect of risk factors, the level-specific change in variance (Ds^2) was equally important at both the individual and district level.

This implies that the risk factors were unequally distributed between individuals and between districts. This could possibly be the reason for the difference in race-wise results between the unadjusted and adjusted estimates. The unadjusted prevalence showed that prevalence was highest in Asian/Caucasians, followed by the mixed race, and lowest in Africans, while the adjusted estimates showed lower chances of hypertension in Asians/Caucasians. This most likely was due to the reduced confounding effect of age, whose average was highest in Asians/Caucasians, followed by the mixed race and lowest for Africans. A previous study found age-standardised self-reported hypertension to be highest in mixed-race women followed by African women.[39]

There were important geographic variations in hypertension prevalence between districts in South Africa, even after controlling for socio-demographic and behavioural background factors. Districts with a lower-than-average prevalence were mostly in the north-eastern part of the country (Limpopo, Mpumalanga and Gauteng provinces) while those with a higher-than-average prevalence were mostly found in the Western, Eastern and Northern Cape provinces. Most of these districts are coastal districts in close vicinity to the Atlantic Ocean. A previous study that limited geographic variation of hypertension to the provincial level found similar clustering of hypertension prevalence.[22]

Identifying districts (sub-units) with high and low hypertension prevalence could be useful in programming public health interventions. Districts with a high hypertension burden could be considered for targeted prevention and control programmes, rather than one national intervention programme. As governments, especially in LMICs, are faced with multiple needs and limited resources, their role of ensuring that all people have equitable access to preventative, curative and rehabilitative health services involves preventing them from developing hypertension and its complications.[40-42] Our study has shown that, although the majority of South African districts had approximately the same burden of hypertension, some had a heavier burden than others, even after accounting for risk factors documented to have a strong influence on hypertension prevalence.

The effects of age and BMI on hypertension prevalence were found to vary from district to district, showing their slopes were higher in some districts relative to others. Health services that address the risks of hypertension, for example body mass, should target such areas.

Strengths and limitations

To the best of our knowledge this is the only study to have estimated the prevalence of hypertension at the district level, taking into consideration the associated risk factors. The study, however, has a few limitations. First, while the study sample was large enough to allow credible estimates of hypertension at the national level, the samples at the district level were not large enough and this resulted in wide confidence intervals for the estimated prevalence rates. Second, although we adjusted for seasonal variation when BP measurements were taken for each subject, it was not possible to fully adjust for ambient temperatures since these measurements were not available in our data set.

Third, although we adjusted for race in the analysis, it is possible that there could be differences within the same race, especially for black South Africans, who are also characterised by different ethnicities/tribes. The data set did not have details on ethnicity or tribe. A few studies in sub-Saharan Africa have shown variability of hypertension by ethnicity. In Nigeria, prevalence of hypertension was found to differ significantly by ethnicity after adjusting for age, gender, place of residence and socio-economic status.[43] Similarly, some evidence of ethnic variation has been reported in Kenya where statistically significant differences between ethnic groups were reported after adjusting for sociodemographic and other cardiovascular risk factors,[44] but a study from Nigeria and Cameroon did not find any association of hypertension with ethnicity.[45] It may be interesting to analyse other aspects of diet and cultural differences in food intake, such as salt and sugar consumption, both of which were not available in our data set, and are known for their strong influence on hypertension.

Conclusions

The results from this study show that there were significant differences in the prevalence of hypertension at the district level. Districts with a higher-than-average prevalence appeared to be clustered together, as were those with a lower-than-average prevalence. An implication of these results is that there could have been other risk factors not captured in the data that were associated with hypertension prevalence and were also distributed unequally between the districts.

It could also mean that there were differentials in the clusters of districts in prevention, management and control of hypertension. Effective management without complete control could imply people living longer with the condition, thereby increasing the prevalence of hypertension. On the other hand, districts with a low prevalence could indicate poor management, which could result in hypertension-related deaths. Alternatively, low prevalence could be a result of either low incidence or effective prevention and control interventions. These could be issues for further related research and in particular an examination of the impact of district-level covariates/factors.

The data sets analysed during the current study are available in the NiDS DataFirst repository: https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/NIDS. We acknowledge the NiDS for providing access to data used for this study.

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