

Increase in blood pressure over a 7-year period in a mixed-ancestry South African population

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Background. An increase in the prevalence of high blood pressure (BP) has been reported globally and in the South African (SA) population.

Objectives. To investigate temporal changes in absolute BP levels and hypertension prevalence in the mixed-ancestry South Africans.

Methods. Participants were from two independent cross-sectional surveys conducted during 2008/09 ($N=928$) and 2014/16 ($N=1\ 969$) in Bellville South, Cape Town, SA. Participants' eligibility was based on several criteria, including age >20 years and neither bedridden nor pregnant. Data were obtained by administered questionnaires, clinical measurements (BP and anthropometry) and biochemical assessments (oral glucose tolerance tests and cotinine levels). Known hypertension was based on a self-reported history of doctor-diagnosed hypertension and ongoing treatment. Comparison across years was based on the crude prevalence of hypertension as well as direct age-standardised prevalence, based on the SA 2011 mixed-ancestry population distribution, in 10-year age increments.

Results. In all, 708 participants (76.3%) in 2008/09 and 1 488 (75.6%) in 2014/16 were female. Between 2008/09 and 2014/16, mean systolic BP increased from 124 to 136 mmHg (absolute mean difference 15 mmHg) and mean diastolic BP from 75 to 85 mmHg (absolute mean difference 9 mmHg) in the overall sample. The prevalence of screen-detected hypertension increased from 11.6% to 24.8%, with a similar increase in males and females, while the prevalence of known cases remained stable. These changes remained significant after adjustment for age and gender.

Conclusions. A rightward shift in absolute BP translated into a significant increase in the prevalence of hypertension over time in this population. The predominant increases in screen-detected hypertension suggest that the deteriorating profile was not matched by efforts to detect and manage individuals with higher-than-optimal BP levels.

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Hypertension is the most prevalent non-communicable disease (NCD) risk factor, estimated to affect two in five adults globally and responsible for ~9.4 million deaths each year.^[1] The highest prevalence of hypertension, at 46%, is in the World Health Organization (WHO)'s African Region, where it is frequently undiagnosed.^[1,2] Undiagnosed hypertension is of concern because of the serious complications associated with raised blood pressure (BP). These include cardiovascular diseases such as strokes and heart attacks, kidney failure, cognitive impairment and blindness.^[3,4]

The prevalence of hypertension in South Africa (SA) is high, similar to rates reported on the rest of the continent. In the 2016 South African Demographic and Health Survey (SADHS)^[5] the prevalence was 46% and 44% in ≥ 15 -year-old females and males, respectively. These figures represent a high and rising burden of hypertension in the country, the prevalence having increased 1.8 - 2-fold by 2016^[5] compared with 1998, when it was 25% in females and 23% in males.^[6] The prevalence of hypertension in national surveys generally reflects findings in black Africans, who comprise the majority of SA's population (80.8%).^[7] The other historically defined SA population groups include white (8.0%), Indian/Asian (2.5%) and coloured or mixed-ancestry individuals (8.8%); the latter have Khoisan, white, black and Malay heritage.^[7] In the 2016 SADHS,^[5] mixed-ancestry females and males had a much higher prevalence of hypertension (57% and 58%, respectively) than their black

African counterparts (females 44%, males 41%). The prevalence of hypertension in the mixed-ancestry population was 1.9-fold and 2.2-fold higher in 2016 compared with 1998, when it was 30% in females and 26% in males.^[5,6]

Objectives

The above findings, from a national study, are not generalisable to specific communities in SA because of urban-rural, provincial, population group and other differences. These data should therefore not be used to estimate the hypertension prevalence and patterns in the mixed-ancestry population of Cape Town, for which there is a dearth of recent information. Determining accurate hypertension prevalence and patterns at a local level is necessary to allocate healthcare resources optimally and appropriately and develop cost-effective therapeutic strategies and programmes for that community.

The objective of this study was therefore to investigate the temporal changes in absolute BP levels and hypertension prevalence from 2008/09 to 2014/16 in the mixed-ancestry population of Bellville South, a suburb of Cape Town, Western Cape Province, SA.

Methods

Study population and sampling procedure

The present study was a comparison of two independent cross-sectional studies conducted in 2008/09 and 2014/16 in the

predominantly mixed-ancestry population of Bellville South. The mixed-ancestry population, also known as coloured, has 32 - 43% Khoisan (indigenous South Africans), 20 - 36% Bantu-speaking African, 21 - 28% European and 9 - 11% Asian ancestry and is unique to SA.^[8] Bellville South township (i.e. underdeveloped urban area) is located in the northern suburbs of Cape Town and was founded in the late 1950s. The initial study was conducted in ≥ 18 -year-old residents and the second study in ≥ 20 -year-olds, using randomised street selection. Trained fieldworkers approached every dwelling in the selected streets and invited all potential individuals from each household who fulfilled the inclusion criteria to participate. If there was no answer, the recruiters would make a note and then move to the next house, making it difficult to determine the number of non-responders in both studies. During the 2008/09 survey, 946 subjects were recruited, as previously described by Zemlin *et al.*,^[9] and during the 2014/16 survey an additional 1 989 subjects were recruited. Consenting individuals living in Bellville South, of mixed ancestry, ≥ 20 years of age and neither bedridden nor pregnant, were included.

Ethics approval and consent to participate

Ethics approval for the 2008/09 and 2014/16 studies was obtained from the Cape Peninsula University of Technology (ref. nos CPUT/HW-REC 2008/002 and CPUT/HW-REC 2015/H01, respectively), while ethics approval for the present study was obtained from the University of Cape Town Human Research Ethics Committee (ref. no. 442/2016). Permission to conduct the analysis was granted by the City of Cape Town and community management. All participants had provided written informed consent.

Data collection

Trained research personnel administered questionnaires and collected clinical and biochemical measurements at a designated research site. Anthropometric measurements, including weight, height, and hip and waist circumferences, were obtained using standardised techniques as prescribed by the WHO.^[10] Each measurement was taken three times and then averaged. Registered nurses measured the participants' BPs, using electronic BP monitors; BP readings were taken three times at 3-minute intervals,^[10] and the lowest systolic BP (SBP) and corresponding diastolic BP (DBP) readings were used. Participants with no history of clinically diagnosed diabetes mellitus underwent a 75 g oral glucose tolerance test (OGTT) as recommended by the WHO.^[11]

Definitions

Level of education was categorised into two groups, namely ≤ 7 years of education (completion of primary school) and > 7 years (secondary schooling and higher). Body mass index (BMI, kg/m^2) was defined as normal weight ($< 25.0 \text{ kg}/\text{m}^2$), overweight ($25.0 - 29.9 \text{ kg}/\text{m}^2$) and obese ($\geq 30.0 \text{ kg}/\text{m}^2$). Known hypertension was defined as individuals who were diagnosed as hypertensive and currently on medication, and screen-detected hypertension as BP $\geq 140/90$ mmHg. Diabetes was defined as a fasting plasma glucose level ≥ 7.0 mmol/L and/or a 2-hour post-OGTT plasma glucose level ≥ 11.1 mmol/L, or self-reported on diabetes medication. Prediabetes was defined as a fasting plasma glucose level between 6.1 mmol/L and 6.9 mmol/L and/or a post 2-hour glucose level between 7.8 mmol/L and 11.1 mmol/L.^[11] Current tobacco use was defined as a cotinine level > 10 ng/mL.^[12,13] Alcohol consumption was self-reported.

Statistical analysis

The software programmes Statistica version 13 (Dell, USA) and SPSS version 24 (IBM, USA) were used for data analysis. The results

are reported as means, standard deviations (SDs), percentages and confidence intervals (CIs). Student's *t*-test was used to assess the significance of absolute differences in mean BP over time, while the χ^2 test was used for categorical variables. The crude prevalence of hypertension as well as the direct age-standardised prevalence, based on the SA 2011 mixed-ancestry population distribution, were estimated in 10-year age increments.^[14] Multivariable linear regression, adjusted for age, gender and years of study, assessed the effects of BMI, waist circumference, diabetes status, tobacco and alcohol use, and level of education on absolute BP levels. Equivalent logistic regression models, adjusted for age, gender and year of study, investigated the predictors of hypertension overall (known and screen detected) and separately for screen-detected hypertension. A *p*-value < 0.05 characterised statistically significant results.

Results

The final sample size for the 2008/09 survey was 928 after excluding participants aged < 20 years, 5 non-consenting individuals and a single participant who withdrew from the study. The final sample size for the 2014/16 survey was 1 969 after excluding 10 participants who were not eligible and 10 who withdrew from the study.

Differences between participants in 2008/09 and 2014/16

The majority of participants in both studies were female (2008/09: 76.3%, $n=708$, and 2014/16: 75.6%, $n=1 488$) (Table 1). In 2014/16, participants were younger than in the 2008/09 study (mean age: overall 49.6 v. 54.3 years, respectively, females 50.3 v. 53.7 years, and males 47.4 v. 56.3 years; all $p < 0.001$). The level of education was similar across both surveys (all $p > 0.612$), with about two-thirds of participants having completed > 7 years of education.

Within the surveys, male v. female differences were observed for some characteristics, but not consistently across the two surveys, specifically with regard to males being younger in 2014/16 compared with 2008/09 (Table 1). This translated across anthropometric and behavioural findings for males, with weight, BMI, waist and hip measurements and diabetes status being lower in 2014/16 compared with 2008/09. Furthermore, although the overall BMI decreased marginally between 2008/09 and 2014/16 (mean (SD) 29.9 (7.3) v. 29.2 (8.0) kg/m^2), with a non-significant decrease in females (31.0 v. 30.7 kg/m^2 ; $p=0.349$), BMI decreased significantly in males (26.1 v. 24.6 kg/m^2 ; $p=0.003$). In 2008/09 and 2014/16, the percentage of current alcohol users was similar overall (27.3% v. 26.6%) and in females (21.2% v. 22.3%), but decreased in males (47.0% v. 39.5%; $p < 0.001$). The proportion of current smokers increased in all groups over the 7-year period: 42.5% v. 49.8% overall, 40.9% v. 46.2% in females, and 47.7% v. 60.8% in males (all $p < 0.019$).

Differences in BP and hypertension between 2008/09 and 2014/16

Mean BP levels increased between 2008/09 and 2014/16 from 124 mmHg to 136 mmHg for SBP and from 75 mmHg to 85 mmHg for DBP in the overall sample (both $p < 0.001$). A similar pattern was observed for males and females (Figs 1 and 2). Between 2008/09 and 2014/16, the greatest increases for SBP were 19 mmHg in females and 13 mmHg in males, while for DBP these were 12 mmHg and 9 mmHg in males and females, respectively (Fig. 1).

The crude and age-standardised hypertension prevalence increased from 48.4% and 30.7%, respectively, in 2008/09 to 59.1% and 45.0% in 2014/16 ($p < 0.001$). Of concern was the high proportion of screen-detected or unknown hypertension, which more than doubled between 2008/09 and 2014/16; the crude prevalence increased from 11.6% to 24.8% and the age-standardised prevalence from 8.3%

Table 1. Comparison of the characteristics of study participants in 2008/09 and 2014/16 by gender

	Overall				Female				Male				F v. M			
	2008/09 (N=928)		2014/16 (N=1 969)		2008/09 (N=708)		2014/16 (N=1 488)		2008/09 (N=220)		2014/16 (N=481)		2008/09		2014/16	
	n/N (%)	mean (SD)	n/N (%)	mean (SD)	n/N (%)	mean (SD)	n/N (%)	mean (SD)	n/N (%)	mean (SD)	n/N (%)	mean (SD)	p-value	p-value	p-value	p-value
Age (years), mean (SD)	54.3 (14.7)	49.6 (15.2)	53.7 (14.4)	50.3 (14.9)	53.7 (14.4)	50.3 (14.9)	53.7 (14.4)	50.3 (14.9)	56.3 (15.2)	47.4 (15.7)	56.3 (15.2)	47.4 (15.7)	<0.001	0.022	<0.001	<0.001
Level of education, n/N (%)																
≤7 years	324/920 (35.2)	670/1 956 (34.3)	259/702 (36.9)	531/1 479 (35.9)	259/702 (36.9)	531/1 479 (35.9)	259/702 (36.9)	531/1 479 (35.9)	65/218 (29.8)	139/477 (29.1)	65/218 (29.8)	139/477 (29.1)	0.653	0.056	0.856	0.007
>7 years	596/920 (64.8)	1 286/1 956 (65.7)	443/702 (63.1)	948/1 479 (64.1)	443/702 (63.1)	948/1 479 (64.1)	443/702 (63.1)	948/1 479 (64.1)	153/218 (70.2)	338/477 (70.9)	153/218 (70.2)	338/477 (70.9)	<0.001	<0.001	<0.001	<0.001
Alcohol use, n/N (%)																
Currently drinking	250/915 (27.3)	519/1 957 (26.6)	148/698 (21.2)	330/1 479 (22.3)	148/698 (21.2)	330/1 479 (22.3)	148/698 (21.2)	330/1 479 (22.3)	102/217 (47.0)	189/478 (39.5)	102/217 (47.0)	189/478 (39.5)	<0.001	<0.001	<0.001	<0.001
Non-drinker	474/915 (51.8)	1 229/1 957 (62.8)	413/698 (59.2)	1 005/1 479 (68.0)	413/698 (59.2)	1 005/1 479 (68.0)	413/698 (59.2)	1 005/1 479 (68.0)	61/217 (28.1)	224/478 (46.9)	61/217 (28.1)	224/478 (46.9)	0.019	<0.001	0.022	<0.001
Past drinker	191/915 (20.9)	209/1 957 (10.6)	137/698 (19.6)	144/1 479 (9.7)	137/698 (19.6)	144/1 479 (9.7)	137/698 (19.6)	144/1 479 (9.7)	54/217 (24.9)	65/478 (13.6)	54/217 (24.9)	65/478 (13.6)	0.349	<0.001	0.003	<0.001
Tobacco use, n/N (%)																
Smoker	392/923 (42.5)	950/1 909 (49.8)	288/705 (40.9)	666/1 442 (46.2)	288/705 (40.9)	666/1 442 (46.2)	288/705 (40.9)	666/1 442 (46.2)	104/218 (47.7)	284/467 (60.8)	104/218 (47.7)	284/467 (60.8)	0.019	0.074	0.001	<0.001
Non-smoker	531/923 (57.5)	959/1 909 (50.2)	417/705 (59.1)	776/1 442 (53.8)	417/705 (59.1)	776/1 442 (53.8)	417/705 (59.1)	776/1 442 (53.8)	114/218 (52.3)	183/467 (39.2)	114/218 (52.3)	183/467 (39.2)	0.308	<0.001	0.053	<0.001
Weight (kg), mean (SD)	74.9 (17.9)	74.1 (19.8)	75.4 (18.1)	75.3 (19.9)	75.4 (18.1)	75.3 (19.9)	75.4 (18.1)	75.3 (19.9)	73.1 (17.1)	70.1 (19.0)	73.1 (17.1)	70.1 (19.0)	0.003	<0.001	0.022	<0.001
Height (cm), mean (SD)	158.7 (8.7)	159.7 (8.6)	156.0 (7.0)	156.7 (6.6)	156.0 (7.0)	156.7 (6.6)	156.0 (7.0)	156.7 (6.6)	167.5 (8.0)	169.0 (7.5)	167.5 (8.0)	169.0 (7.5)	0.031	<0.001	0.003	<0.001
BMI (kg/m ²), mean (SD)	29.9 (7.3)	29.2 (8.0)	31.0 (7.2)	30.7 (7.9)	31.0 (7.2)	30.7 (7.9)	31.0 (7.2)	30.7 (7.9)	26.1 (6.2)	24.6 (6.4)	26.1 (6.2)	24.6 (6.4)	<0.001	<0.001	<0.001	<0.001
Waist circumference (cm), mean (SD)	97.1 (14.9)	92.6 (17.1)	98.0 (14.7)	94.7 (16.7)	98.0 (14.7)	94.7 (16.7)	98.0 (14.7)	94.7 (16.7)	94.1 (15.1)	86.1 (16.6)	94.1 (15.1)	86.1 (16.6)	<0.001	0.001	<0.001	<0.001
Hip circumference (cm), mean (SD)	109.8 (14.8)	104.5 (16.4)	112.7 (14.9)	107.7 (16.2)	112.7 (14.9)	107.7 (16.2)	112.7 (14.9)	107.7 (16.2)	100.3 (10.0)	94.5 (12.5)	100.3 (10.0)	94.5 (12.5)	<0.001	<0.001	<0.001	<0.001
SBP (mmHg), mean (SD)	123.5 (19.2)	136.0 (25.9)	122.5 (19.5)	136.3 (25.7)	122.5 (19.5)	136.3 (25.7)	122.5 (19.5)	136.3 (25.7)	126.6 (18.0)	135.0 (26.5)	126.6 (18.0)	135.0 (26.5)	<0.001	0.007	<0.001	0.320
DBP (mmHg), mean (SD)	74.9 (12.5)	85.2 (14.9)	74.5 (12.7)	85.8 (14.5)	74.5 (12.7)	85.8 (14.5)	74.5 (12.7)	85.8 (14.5)	76.3 (11.7)	83.5 (15.8)	76.3 (11.7)	83.5 (15.8)	<0.001	0.068	<0.001	<0.001
Pulse rate (bpm), mean (SD)	74.0 (11.7)	72.3 (12.8)	74.4 (11.7)	73.4 (12.5)	74.4 (11.7)	73.4 (12.5)	74.4 (11.7)	73.4 (12.5)	72.7 (11.7)	68.9 (13.1)	72.7 (11.7)	68.9 (13.1)	0.06	0.057	<0.001	<0.001
Diabetic status, n/N (%)																
Diabetes	266/925 (28.8)	384/1 960 (19.6)	198/705 (28.1)	310/1 480 (20.9)	198/705 (28.1)	310/1 480 (20.9)	198/705 (28.1)	310/1 480 (20.9)	68/220 (30.9)	74/480 (15.4)	68/220 (30.9)	74/480 (15.4)	<0.001	0.622	<0.001	<0.001
Prediabetes	185/925 (20)	298/1 960 (15.2)	145/705 (20.6)	243/1 480 (16.4)	145/705 (20.6)	243/1 480 (16.4)	145/705 (20.6)	243/1 480 (16.4)	40/220 (18.2)	55/480 (11.5)	40/220 (18.2)	55/480 (11.5)	<0.001	<0.001	<0.001	<0.001
Normal	474/925 (51.2)	1278/1 960 (65.2)	362/705 (51.3)	927/1 480 (62.6)	362/705 (51.3)	927/1 480 (62.6)	362/705 (51.3)	927/1 480 (62.6)	112/220 (50.9)	351/480 (73.1)	112/220 (50.9)	351/480 (73.1)	<0.001	<0.001	<0.001	<0.001

F v. M = female v. male; SD = standard deviation; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; bpm = beats per minute.

to 22.9% (both $p < 0.003$). Crude screen-detected hypertension by gender increased in both females (11.0% to 23.7%; $p < 0.001$) and males (13.6% to 28.3%; $p < 0.001$).

In contrast, the prevalence of known hypertension in the overall sample mostly remained stable: 36.7% in 2008/09 v. 34.3% in 2014/16 for crude prevalence, and 22.4% v. 22.1% for age-standardised prevalence. However, this concealed a significant decrease in known hypertension prevalence for males from 34.5% to 22.7% ($p = 0.013$); there was minimal change for females (37.4% v. 38.1%; $p = 0.838$) (Table 2). There was evidence of interaction by gender in the change of hypertension prevalence across years (known hypertension: $p = 0.030$ for gender*year and screen-detected hypertension: $p < 0.001$ for gender*year; Table 2).

Furthermore, when comparing the relationship between age and hypertension prevalence, there was a highly significant decrease in the mean (SD) age of participants with screen-detected hypertension from 58.6 (14.5) years in 2008/09 to 51.0 (13.8) years in 2014/16 ($p < 0.001$). Although the prevalence of screen-detected hypertension increased with age in 2008/09, peaking in the oldest age group (17.8%), in 2014/16 it peaked in the 40 - 49-year age group (31.9%) (Fig. 3).

Determinants of changes in BP and hypertension

In linear regression models, data from the two surveys were combined and adjusted for age, gender and year of study. Compared with 2008/09, the participants in 2014/16 had 15.6 mmHg (95% CI 13.9 - 17.4) higher SBP and 11.1 mmHg (95% CI 10.0 - 12.2) higher DBP. Furthermore, age, BMI, waist circumference, diabetes, prediabetes, current smoking and current alcohol use were associated with both SBP and DBP, while higher education level was inversely associated with SBP (Table 3).

In an expanded multivariable model using a backward selection method of the above variables,

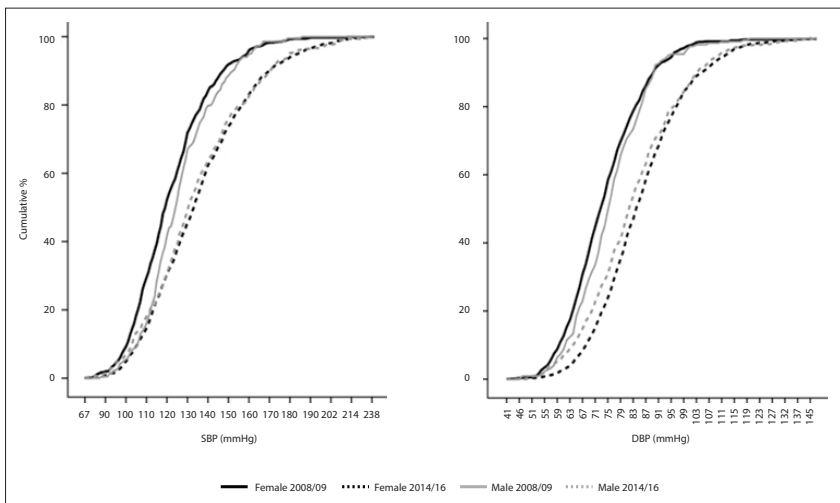


Fig. 1. Cumulative distribution of overall hypertension status (normal, known hypertension and screen-detected hypertension) by SBP and DBP for 2008/09 and 2014/16. (SBP = systolic blood pressure; DBP = diastolic blood pressure.)

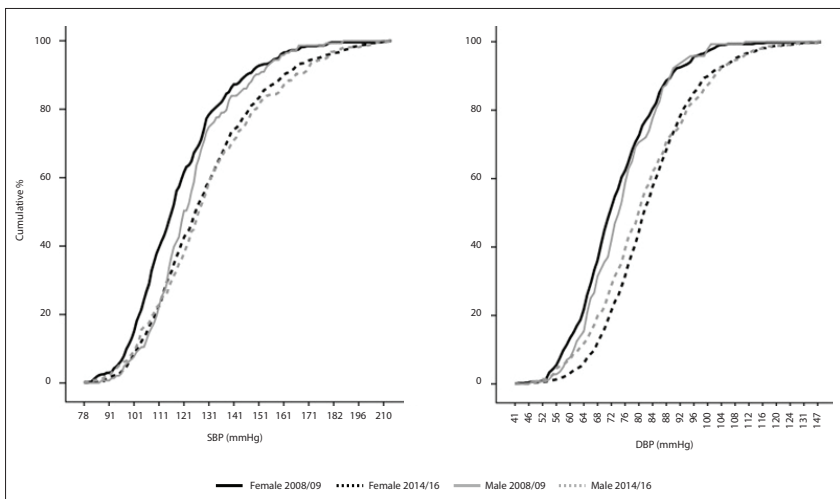


Fig. 2. Cumulative distribution of screen-detected hypertension by SBP and DBP for 2008/09 and 2014/16. (SBP = systolic blood pressure; DBP = diastolic blood pressure.)

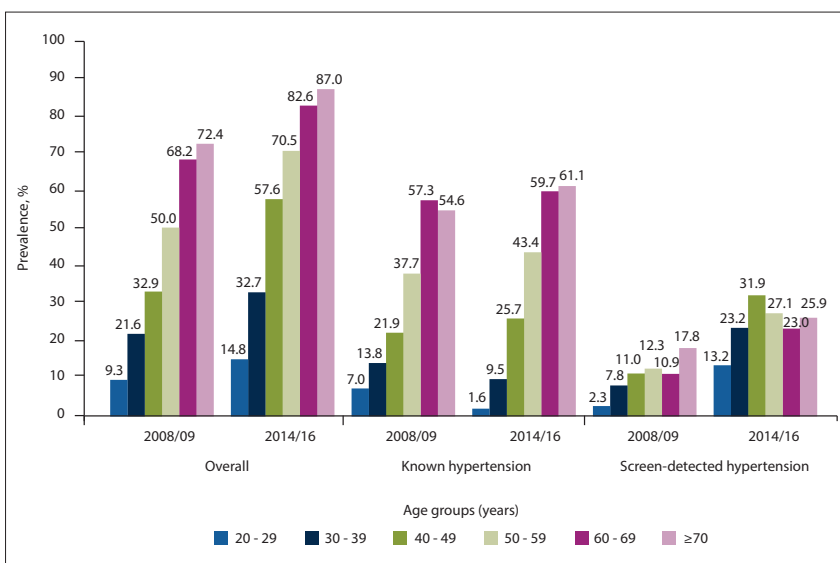


Fig. 3. Comparison of the prevalence of hypertension (overall, known and screen detected) between 2008/09 and 2014/16 by age group.

age, BMI, abnormal glucose tolerance and current drinking were associated with both SBP and DBP, while higher education level was inversely associated with SBP (Table 4). Furthermore, the model showed that the study period, i.e. 2014/16 as opposed to 2008/09, was associated with higher SBP (16.0 mmHg; 95% CI 14.2 - 17.7), as well as higher DBP (11.5 mmHg; 95% CI 10.7 - 12.9).

In logistic regression models adjusted for age, gender and year of study, participants in 2014/16 compared with 2008/09 had almost 3-fold higher odds of hypertension (odds ratio (OR) 2.83, 95% CI 2.33 - 3.45). The odds for screen-detected hypertension were 4-fold greater (OR 4.33, 95% CI 3.29 - 5.69) (Table 5). Older age, current alcohol use, and overweight and obesity were associated with higher odds of hypertension and screen-detected hypertension (Table 5). Additionally, diabetes was significantly associated with hypertension, while lower education level was related to screen-detected hypertension; the OR for the latter was lower for past drinking v. no drinking.

Discussion

Increases in overall hypertension prevalence over a 7-year period

The present study showed a highly significant increase in overall hypertension prevalence in the mixed-ancestry population living in Cape Town. Results from two cross-sectional studies conducted in the same community (Bellville South) showed a 1.5-fold increase in age-standardised hypertension over a 7-year period from 2008/09 (30.7%) to 2014/16 (45.0%). The rise in hypertension prevalence in this community over 7 years was similar to that reported by Peer *et al.*^[3] for black Africans in Cape Town over an 18-year period (a 1.8-fold increase from 21.6% to 38.9%).^[3] These increases may reflect differential contributors to hypertension in these communities, but probably represent an accelerated increase in hypertension risk factors over time. Peer *et al.*^[3] conducted their comparison between 1990 and 2008/09, while the present comparison was between 2008/09 and 2014/16. Rapid increases in urbanisation over the past decade and the associated growth of hypertension risk factors may be contributing to a steep non-linear rise in hypertension in Cape Town.

High prevalence of screen-detected hypertension

The high prevalence of screen-detected hypertension (50%) in 2014/16 and the almost 3-fold increase in screen-detected hypertension between 2008/09 and

Table 2. Crude and age-standardised prevalence of hypertension in 2008/09 and 2014/16, by gender and year

	Overall			Female			Male		
	2008/09 (N=928)	2014/16 (N=1 969)	p-value	2008/09 (N=708)	2014/16 (N=1 488)	p-value	2008/09 (N=220)	2014/16 (N=481)	p-value
Crude prevalence of hypertension: BP ≥140/90 mmHg and on treatment, % (95% CI)	36.7 (33.7 - 40)	34.3 (32.2 - 36.5)	0.380	37.4 (33.9 - 41.1)	38.1 (35.6 - 40.6)	0.838	34.5 (28.4 - 41.3)	22.7 (19 - 26.7)	0.013
Known hypertension	11.6 (9.7 - 13.9)	24.8 (22.9 - 26.8)	<0.001	11.0 (8.9 - 13.6)	23.7 (21.5 - 25.9)	<0.001	13.6 (9.5 - 19.1)	28.3 (24.3 - 32.6)	0.007
Screen-detected hypertension	48.4 (45.1 - 51.7)	59.1 (56.9 - 61.3)	0.003	48.4 (44.7 - 52.2)	61.8 (59.2 - 64.2)	0.002	48.2 (41.4 - 55)	50.9 (46.4 - 55.5)	0.695
Age-standardised prevalence of hypertension, % (95% CI)	22.4 (22.4 - 22.5)	22.1 (22.0 - 22.1)	<0.001	23.4 (23.3 - 23.5)	25.3 (25.2 - 25.3)	<0.001	21.9 (21.9 - 22)	14.1 (14.1 - 14.2)	<0.001
Known hypertension	8.3 (8.2 - 8.3)	22.9 (22.9 - 23.0)	<0.001	8.0 (7.9 - 8.0)	22.5 (22.4 - 22.5)	<0.001	8.2 (8.2 - 8.2)	24.7 (24.6 - 24.8)	<0.001
Screen-detected hypertension	30.7 (30.7 - 30.8)	45.0 (44.9 - 45.0)	<0.001	31.4 (31.3 - 31.4)	47.7 (47.7 - 47.8)	<0.001	30.1 (30 - 30.2)	38.8 (38.8 - 38.9)	<0.001
Known and screen-detected hypertension									

F v. M = female v. male; CI = confidence interval.

2014/16 are of concern, demonstrating failure of the healthcare system to provide adequate hypertension detection and treatment services in the mixed-ancestry population in Cape Town. Despite the high and rising prevalence of hypertension in this community, the stable prevalence of known hypertension indicates that minimal screening efforts are being undertaken. This situation is unacceptable in view of the severity of hypertension-related complications and the minimal costs involved, apart from time, in measuring BP. An increase in hypertension awareness in the community and a concerted drive by the healthcare sector to promote hypertension screening and to 'know your numbers' are required. These efforts need to be accompanied by an increase in healthcare resources such as staff and medication to optimally treat the high burden of screen-detected hypertension.

The National Department of Health (NDoH) in SA prioritised the management of NCDs at the South African Summit on the Prevention and Control of NCDs in 2011. One of the goals was to reduce the prevalence of raised BP by 20% by 2020.^[15] However, the numerous good legislative and policy initiatives formulated by the NDoH for the control and management of hypertension over the past two decades have unfortunately not been translated into successful action, as demonstrated the findings of the present study.

Our results primarily reflect a significant increase in newly diagnosed cases of hypertension, with a stable known hypertension prevalence. Despite provision by the SA government of guidelines to increase awareness of NCDs, large numbers of individuals are unaware of their hypertensive status, clearly indicating that the hypertension epidemic exceeds efforts to detect, treat and control the disease and suggesting that hypertension, which has been called the 'silent killer' because symptoms are absent in the early stages,^[16] may need to be combated with tactics different to those that have been used so far. Although the government is implementing strategies to control NCDs, opportunistic screening at healthcare facilities is generally still relied on to diagnose hypertension, and difficulties in physical access to healthcare and low socioeconomic status are further major challenges in curbing NCD rates. Approximately two-thirds of the Western Cape population lives in the City of Cape Town, which results in overburdened public healthcare facilities with long queues and staff shortages.^[17,18] Access to private healthcare is only available to those people who are able to afford the facilities or are on a medical aid. Our findings therefore suggest that further strategies are required to create awareness programmes and screening opportunities aimed at reducing or preventing further increases in NCDs, and that these must be accompanied by solutions to the causal effects of the increase in hypertension prevalence.

Shift in peak prevalence from old age to middle age

In contrast to the 2008/09 findings and global trends in general,^[16] in 2014/16 hypertension prevalence peaked at a much younger age. This was particularly true for screen-detected hypertension, where the prevalence peaked in 40 - 49-year-olds in 2014/16 as opposed to ≥70-year-olds in 2008/09. The shift in peak hypertension prevalence by age was unexpected, and may be due to earlier, sustained and longer exposures to lifestyle-related risk factors than those experienced a decade ago. Hypertension is now affecting the younger working-age population in this community, who are in their prime; a decade ago, it was the older retired members of society who most commonly developed the disease. This change will have far-reaching social and financial effects, as the loss of breadwinners who succumb to uncontrolled hypertension and its complications drains household incomes and perpetuates the cycle of poverty.

Table 3. Age, gender and year of study adjusted linear regression models for determinants of absolute BP levels*

	Model 1: SBP				Model 2: DBP			
	β	95% CI		<i>p</i> -value	β	95% CI		<i>p</i> -value
		Lower limit	Upper limit			Lower limit	Upper limit	
Year of study	15.6	13.9	17.4	<0.001	11.1	10.0	12.2	<0.001
Gender (male)	1.1	-0.7	3.0	0.233	-0.8	-2.0	0.4	0.180
Age (per 5 years)	3.3	3.1	3.6	<0.001	0.8	0.6	1.0	<0.001
BMI	0.4	0.3	0.6	<0.001	0.4	0.3	0.5	<0.001
Waist circumference	0.2	0.2	0.3	<0.001	0.2	0.2	0.2	<0.001
Diabetes	6.1	4.0	8.2	<0.001	2.3	0.9	3.6	<0.001
Prediabetes	4.4	2.1	6.6	<0.001	2.4	0.9	3.8	<0.001
Current smoking	-1.9	-3.6	-0.2	0.029	-1.6	-2.7	-0.6	<0.001
Secondary level of education or higher	-2.3	-4.1	-0.5	0.012	-1.0	-2.2	0.1	0.090
Current drinking	3.0	1.0	5.0	0.003	2.5	1.2	3.7	<0.001
Past drinking	-2.2	-4.6	0.2	0.081	-0.6	-2.2	0.9	0.420

BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; β = beta-coefficient; CI = confidence interval; BMI = body mass index.

*In Table 3, two linear regression models showing the relationship between SBP (model 1) and DBP (model 2) were used with variables known to be associated with high BP. Each model was adjusted for age, gender and year of study. In both models BMI, waist circumference, diabetes, prediabetes, current smoking and current drinking were found to be significant, with level of education only being significant in SBP.

Table 4. Age, gender and year of study adjusted multivariate linear regression models for determinants of absolute BP levels*

	Model 1: SBP				Model 2: DBP			
	β	95% CI		<i>p</i> -value	β	95% CI		<i>p</i> -value
		Lower limit	Upper limit			Lower limit	Upper limit	
Year of study	16.0	14.2	17.7	<0.001	11.8	10.7	12.9	<0.001
Gender (male)	3.5	1.5	5.4	0.001	0.6	-0.7	1.8	0.37
Age (per 5 years)	2.9	2.6	3.2	<0.001	0.7	0.5	0.9	<0.001
BMI	0.4	0.3	0.6	<0.001	0.2	0.1	0.3	<0.001
Diabetes	4.9	2.8	7.0	<0.001				
Prediabetes	3.1	0.9	5.4	0.006				
Secondary level of education or higher	-2.3	-3.8	-0.8	0.003				
Current drinking	3.0	1.0	5.0	0.003	3.5	2.3	4.7	<0.001

BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; β = beta-coefficient; CI = confidence interval; BMI = body mass index.

*In Table 4, a backward elimination linear regression was done. This meant that all variables were used in the model and the variables with the most statistically insignificant decline were deleted, one by one, until a final model was determined with only statistically significant variables. Each model was adjusted for age, gender and year of study. Therefore, in model 1, the variables that indicated significance were BMI, diabetes, prediabetes, education level and current drinking, while model 2 showed BMI and current drinking as the only significant variables.

Similar findings have been reported in developing countries such as China and India. Wang *et al.*^[19] reported an increase in hypertension prevalence in China between 1991 and 2011, with the greatest rise (68%) in females aged 35 - 44 years. Similarly, Roy *et al.*^[20] reported that the highest prevalence of change between 1991 and 2012 in India was in the age group 35 - 44 years. However, these findings contrast with reports in general, where the increase in hypertension has been reported as mostly due to 'an ageing world population',^[16] with longer life expectancy resulting in increased exposure to risk factors.^[16] It is unclear from the results of the present study why there was a shift in the peak prevalence of hypertension to middle age, but it may have been due to changes in lifestyle and/or environmental surroundings, including working environments. With regard to the latter, SA has recently been reclassified as a middle- to high-income country by the World Bank,^[21] suggesting that working conditions may be becoming more stressful. However, the increased burden of disease in younger individuals will increase the load on the healthcare system, and more importantly affect the economy because people affected by the disease are in the prime of their working careers. Efforts aimed at screening therefore need to be intensified in this age group. Regular screening for raised BP could be effective in detecting the disease at an early stage and could possibly be used by management dealing with workloads and responsibilities in stressful work environments.

Risk factors associated with hypertension

The traditional risk factors for hypertension of obesity and alcohol intake were significantly associated with hypertension in this study, highlighting the influence of urbanisation and other environmental factors on the development of the disease. However, smoking was not positively associated with hypertension, similar to findings in black Africans in Cape Town.^[3]

The association of diabetes with hypertension was unsurprising. It underscores the frequent coexistence of these diseases and that, if one is present, the other should be screened for. Lifestyle and cultural norm changes such as decreased physical activity are well known aspects of modern working environments. Similarly, changes in traditional habits of males and females, such as the increase in smoking and drinking among females (and the increase in smoking among males) in the 2014/16 study population, are major factors that fuel the NCD epidemic in developing countries.^[22,23]

Results from the present study showed alcohol consumption to be positively and smoking inversely associated with BP (both SBP and DBP), but the association with smoking became non-significant after using backward selection in a multivariate selection model. However, the phenomenon of an inverse association between smoking and high BP has also been reported in the 2014 China National Health Survey, where smoking was associated with

Table 5. Age, sex and year of study adjusted ORs (with 95% CIs) for the determinants of overall hypertension and screen-detected hypertension

Variables in each model	Overall hypertension (N=2 897)		Screen-detected hypertension (N=1 852)	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Year		<0.001		<0.001
2008/09	1		1	
2014/16	2.83 (2.33 - 3.45)		4.33 (3.29 - 5.69)	
Age (years)		<0.001		<0.001
20 - 29	1		1	
30 - 39	2.46 (1.62 - 3.75)		2.18 (1.37 - 3.48)	
40 - 49	5.65 (3.79 - 8.41)		4.50 (2.89 - 7.02)	
50 - 59	9.55 (6.39 - 14.27)		5.36 (3.40 - 8.44)	
60 - 69	18.27 (11.84 - 28.21)		8.20 (4.95 - 13.60)	
≥70	26.46 (16.31 - 42.93)		14.54 (8.2 - 25.80)	
Gender		0.938		0.110
Female	1		1	
Male	1.01 (0.81 - 1.26)		1.24 (0.95 - 1.63)	
Level of education		0.750		0.040
Primary or lower	1		1	
Secondary or higher	0.75 (0.61 - 0.91)		0.77 (0.60 - 0.99)	
Alcohol use		<0.001		<0.001
Non-drinker	1		1	
Current drinker	1.56 (1.24 - 1.96)		1.81 (1.38 - 2.38)	
Past drinker	0.94 (0.72 - 1.23)		0.58 (0.39 - 0.86)	
Tobacco use		0.870		0.271
Non-smoker	1		1	
Smoker	0.87 (0.71 - 1.05)		0.87 (0.68 - 1.11)	
BMI category		<0.001		<0.001
Normal	1		1	
Overweight	1.52 (1.19 - 1.94)		1.45 (1.07 - 1.96)	
Obese	2.56 (2.02 - 3.24)		2.11 (1.57 - 2.84)	
Diabetic status		<0.001		0.249
Normal	1		1	
Prediabetic	1.17 (0.92 - 1.49)		0.98 (0.72 - 1.34)	
Diabetic	2.40 (1.88 - 3.07)		1.31 (0.94 - 1.82)	

OR = odds ratio; CI = confidence interval; BMI = body mass index.

lower BP, while cessation of smoking was linked to increased hypertension.^[16,24]

Study strengths and limitations

The strength of this study is that the two surveys were conducted in the population from the same geographical area, using similar procedures. However, the study has the following limitations: (i) it consisted of only two cross-sectional surveys, which prevented reliable assessment of trends; (ii) the second study was not a follow-up but rather another cross-sectional study collecting new participants from the area; (iii) there was a low proportion of men in the two studies (24%), a common problem in SA research;^[3] (iv) there was no information on high salt intake, which is known to contribute to the development of hypertension; (v) although information on hypertension treatment was obtained from participants, control was not evaluated; and (vi) hypertension target organ damage was not assessed. The latter precluded the evaluation of hypertension control and optimal management across the two surveys.

Conclusions

Our findings have shown a rightward shift in absolute BP in the SA mixed-ancestry population that translated into a significant increase

in the prevalence of hypertension, particularly screen-detected cases, in both males and females over a 7-year period. The traditional risk factors for hypertension of obesity, diabetes and alcohol intake were significantly associated with hypertension in this study, highlighting the influence of urbanisation and other environmental factors on the development of the disease.

A concerted drive on the part of the healthcare sector to increase awareness of hypertension and BP status in this population group is of crucial importance. The severity of hypertension-related complications and the minimal costs involved in measuring BP necessitate screening on a much wider scale than is the case at present, possibly in the workplace as well as in the healthcare environment, to manage and prevent the cardiovascular diseases that result from hypertension.

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- World Health Organization. A Global Brief on Hypertension: World Health Day 2013. Geneva: WHO, 2013. https://www.who.int/cardiovascular_diseases/publications/global_brief_hypertension/en/ (accessed 21 May 2019).
- Ataklte F, Erqou S, Kaptoge S, et al. Burden of undiagnosed hypertension in sub-Saharan Africa: A systematic review and meta-analysis. *Hypertension* 2015;65(2):291-298. <https://doi.org/10.1161/HYPERTENSIONAHA.107.093336>
- Peer N, Steyn K, Lombard C, Gwebushe N, Levitt N. A high burden of hypertension in the urban black population of Cape Town: The Cardiovascular Risk in Black South Africans (CRIBSA) study. *PLoS One* 2013;8(11):e78567. <https://doi.org/10.1371/journal.pone.0078567>
- Ibrahim MM, Damasceno A. Hypertension in developing countries. *Lancet* 2012;380(9841):611-619. [https://doi.org/10.1016/S0140-6736\(12\)60861-7](https://doi.org/10.1016/S0140-6736(12)60861-7)
- National Department of Health, South Africa, South African Medical Research Council and DHS Program, USA. South Africa Demographic and Health Survey 2016: Key Indicators Report. Pretoria: Statistics South Africa, 2017. <https://www.statssa.gov.za/publications/Report%2003-00-09/Report%2003-00-092016.pdf> (accessed 20 May 2019).
- National Department of Health, South Africa. South Africa Demographic and Health Survey 1998. <https://www.dhsprogram.com/pubs/pdf/FR131/FR131.pdf> (accessed 21 May 2019).
- Statistics South Africa. Mid-year population estimates July 2017. Statistical release P0302. Pretoria: Stats SA, 2017. <https://www.statssa.gov.za/publications/P0302/P03022017.pdf> (accessed 21 May 2019).
- De Wit E, Delport W, Rugamika CE, et al. Genome-wide analysis of the structure of the South African coloured population in the Western Cape. *Hum Genet* 2010;128(2):145-153. <https://doi.org/10.1007/s00439-010-0836-1>
- Zemlin AE, Matsha TE, Hassan MS, Erasmus RT. HbA1c of 6.5% to diagnose diabetes mellitus – Does it work for us? – The Bellville South Africa Study. *PLoS One* 2011;6(8):e22558. <https://doi.org/10.1371/journal.pone.0022558>
- World Health Organization. The WHO STEPS Surveillance Manual. Geneva: WHO, 2012. https://apps.who.int/iris/bitstream/handle/10665/43376/9241593830_eng.pdf?sequence=1&isAllowed=y (accessed 22 May 2019).
- World Health Organization. Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia. Geneva: WHO, 2006. https://www.who.int/diabetes/publications/Definition%20and%20diagnosis%20of%20diabetes_new.pdf (accessed 22 May 2019).
- Benowitz NL. The use of biologic fluid samples in assessing tobacco smoke consumption. *Natl Inst Drug Abuse Res Monogr* 1983;48:6-26. https://www.researchgate.net/profile/John_Grabowski/publication/16753447_Issues_in_the_measurement_of_smoking_summary_and_discussion/links/563245a308ae584878091b89/Issues-in-the-measurement-of-smoking-summary-and-discussion.pdf#page=17 (accessed 4 June 2019).
- Caraballo R, Giovino G, Pechacek T. Self-reported cigarette smoking vs. serum cotinine among U.S. adolescents. *Nicotine Tob Res* 2004;6(1):19-25. <https://doi.org/10.1080/14622200310001656821>
- Statistics South Africa. Statistical release (Revised): Census 2011. P0301.4. Pretoria: Stats SA, 2012. <https://www.statssa.gov.za/publications/P03014/P030142011.pdf> (accessed 22 May 2019).
- National Department of Health, South Africa. Strategic Plan for the Prevention and Control of Non-communicable Diseases 2013 - 17. RP06/2013. <http://www.hsrc.ac.za/uploads/pageContent/3893/NCDs%20STRAT%20PLAN%20%20CONTENT%208%20April%20proof.pdf> (accessed 22 May 2019).
- Olsen MH, Angell SY, Asma S, et al. A call to action and a life course strategy to address the global burden of raised blood pressure on current and future generations: The Lancet Commission on Hypertension. *Lancet* 2016;388(10060):2665-2712. [https://doi.org/10.1016/S0140-6736\(16\)31134-5](https://doi.org/10.1016/S0140-6736(16)31134-5)
- Western Cape Government. 2016 Socio-economic Profile: City of Cape Town. 2016. https://www.westerncape.gov.za/assets/departments/treasury/Documents/Socio-economic-profiles/2016/City-of-Cape-Town/city_of_cape_town_2016_socio-economic_profile_sep-lg.pdf (accessed 8 February 2018).
- Western Cape Government Provincial Treasury. Regional Development Profile: City of Cape Town: Working paper. 2012. https://www.westerncape.gov.za/assets/departments/treasury/dc0_city_of_cape_town_sep-lg_profile_02_2013.pdf (accessed 22 May 2019).
- Wang J, Ning X, Yang L, et al. Trends of hypertension prevalence, awareness, treatment and control in rural areas of northern China during 1991 - 2011. *J Hum Hypertens* 2014;28(1):25-31. <https://doi.org/10.1038/jhh.2013.44>
- Roy A, Praveen PA, Amarchand R, et al. Changes in hypertension prevalence, awareness, treatment and control rates over 20 years in National Capital Region of India: Results from a repeat cross-sectional study. *BMJ Open* 2017;7(7):e015639. <https://doi.org/10.1136/bmjopen-2016-015639>
- Fantom NJ, Serajuddin U. The World Bank's Classification of Countries by Income (English). Policy Research Working Paper No. WPS 7528. Washington, DC: World Bank Group, 2016. <http://documents.worldbank.org/curated/en/408581467988942234/The-World-Banks-classification-of-countries-by-income> (accessed 22 May 2019).
- Addo J, Smeeth L, Leon DA. Hypertension in sub-Saharan Africa: A systematic review. *Hypertension* 2007;50(6):1012-1018. <https://doi.org/10.1161/HYPERTENSIONAHA.107.093336>
- Hancock C, Kingo L, Raynaud O. The private sector, international development and NCDs. *Global Health* 2011;7:23. <https://doi.org/10.1186/1744-8603-7-23>
- Li G, Wang H, Wang K, et al. The association between smoking and blood pressure in men: A cross-sectional study. *BMC Public Health* 2017;17(1):1-6. <https://doi.org/10.1186/s12889-017-4802-x>

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