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Association between lifestyle risk factors and incident hypertension among middle-aged and older Australians

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ABSTRACT

This study aimed to examine the association between individual and combined lifestyle risk factors and the incidence of hypertension 1) in middle-aged and older Australians, and 2) to compare findings in men and women. A sample of 32,393 adults aged ≥45 years from New South Wales completed baseline (2006–2008) and follow-up (2010) questionnaires. Self-reported incident hypertension was defined as not having physician-diagnosed hypertension nor taking antihypertensive medications at baseline and reporting a diagnosis/treatment of hypertension at follow-up. High-risk categories for six lifestyle risk factors were defined as: a BMI ≥ 25 kg/m^2, physical activity levels < 150 min/week, consuming ≥14 alcohol drinks/week, being a current smoker, consuming < 2 fruit and/or < 3 vegetable serves/day, and being at high risk of psychological distress (Kessler-10 score ≥ 22). The association between baseline risk factors and incident hypertension was examined using logistic regression models, adjusted for socio-demographic, medical and lifestyle risk factors. After 2.7 (SD: 0.9) years of follow-up, 17.1% developed hypertension. Compared to low-risk categories, high BMI (AOR [95% CI]: 1.99 [1.85, 2.13]), high alcohol intake (1.58 [1.44, 1.73]), low physical activity levels (1.17 [1.07, 1.27]) and being a current smoker (1.15 [1.0, 1.31]) were associated with a higher incidence of hypertension in the overall sample, with similar associations in men and women. The number of high-risk lifestyle factors was positively associated with higher odds of developing hypertension in the overall sample, men and women; with a stronger association in middle-aged men. Adopting a low-risk lifestyle may prevent hypertension among middle-aged and older adults.

1. Introduction

Hypertension is the leading contributor to global disease burden (GBD 2015 Risk Factors Collaborators, 2016). It is one of the major risk factors for cardiovascular disease, which accounts for the largest number of deaths worldwide (GBD 2015 Mortality and Causes of Death Collaborators, 2016; Roth et al., 2017). As the prevalence, mortality, and disease burden of hypertension have increased considerably in the last 25 years (Forouzanfar et al., 2017), it is important to identify modifiable lifestyle risk factors that can inform strategies for hypertension and subsequent cardiovascular disease prevention.

Several lifestyle risk factors for hypertension have been identified, including being overweight or obese, an unhealthy diet, insufficient physical activity and excessive alcohol intake. A plethora of intervention (Dickinson et al., 2006; Neter et al., 2003; Xin et al., 2001) and prospective studies (Briasoulis et al., 2012; Gelber et al., 2007; Lelong et al., 2017; Liu et al., 2017) have examined these factors. Lifestyle factors tend to cluster and have synergistic health effects (Ding et al., 2015a; Krokstad et al., 2017). However, few prospective studies have investigated the combined influence of lifestyle risk factors on the development of hypertension (Cohen et al., 2012; Forman et al., 2009; Banda et al., 2010), and no study to our knowledge has compared these associations in men and women. Given the previously reported sex differences in the prevalence, control, and pathophysiology of hypertension, comparing risk factors in men and women is needed and could inform sex-specific prevention strategies (Doumas et al., 2013).

As most of the attributable global burden of blood-pressure related disease is borne by middle-aged and older people (Lawes et al., 2008), and as the prevalence of hypertension markedly increases with age (Kearney et al., 2005), it is important to examine primary prevention strategies among this age group. The aims of this study are to examine the association between individual and combined lifestyle risk factors and the incidence of hypertension 1) among a cohort of middle-aged and older Australians, and 2) separately in men and women.

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2. Methods

2.1. Study population

The baseline data were from the Sax Institute's 45 and Up Study, a prospective cohort study of 267,153 men and women aged 45 years and over, randomly sampled from the general population of New South Wales (NSW), Australia, using the Medicare database, the national universal health provider. From January 2006 to December 2008, eligible individuals joined the study by completing a postal questionnaire and providing written consent for follow-up. The study methods have been described in detail elsewhere (Banks et al., 2008). In 2010, the first 100,000 participants to join the 45 and Up Study were invited to complete the Social, Economic, and Environmental Factor (SEEF) Study follow-up questionnaire (60.4% response rate). A participant flow chart is provided in Fig. 1. Participants that reported being treated for hypertension or taking antihypertensive medication at baseline were excluded (n = 19,349). Participants that reported being treated for heart disease, high blood cholesterol, or taking medication against heart disease, high blood cholesterol or diabetes were also excluded (n = 20,982) as some of these medications may have blood pressure lowering effects and as people with diabetes commonly have high blood pressure. The final analytic sample included 32,393 participants. The 45 and Up Study was granted ethics approval by the University of NSW Human Research Ethics Committee (reference HREC 05035/HREC 10186) and the SEEF Study by the University of Sydney Human Research Ethics Committee (reference 10-2009/12187).

2.2. Measurement

The baseline and follow-up questionnaires included questions about socio-demographic characteristics, health and lifestyle factors (https://www.saxinstitute.org.au/our-work/45-up-study/questionnaires/).

2.2.1. Ascertainment of hypertension

Incident hypertension was defined, based on self-reported data, as not having physician-diagnosed hypertension nor taking antihypertensive medication at baseline and reporting either a diagnosis or treatment of hypertension at follow-up. Self-reported hypertension has been validated in similar studies involving large cohorts (Forman et al., 2009; Banda et al., 2010).

2.2.2. Baseline exposure variables

Body mass index (BMI), derived from self-reported height and weight, has been previously validated in this cohort (Ng et al., 2011). Physical activity, based on validated questions from the Active Australia Survey was calculated as the sum of time spent on walking, moderate-intensity and vigorous-intensity (weighted by two) physical activity in the past week (Australian Institute of Health and Welfare, 2003). Participants were asked about their weekly alcohol consumption as well as past and current smoking patterns. Usual daily fruit and vegetable consumption was assessed using validated short questions (Rustihauser et al., 2011). Participants' general level of psychological distress was measured using the Kessler-10 (K10) scale, a validated 10-item questionnaire about anxiety and depression symptoms experienced in the previous month (Andrews and Slade, 2001).

2.2.3. Definition of lifestyle risk categories

The six lifestyle factors described above were dichotomised as either low- or high-risk for developing hypertension. A BMI greater or equal to 25 kg/m^2, the standard World Health Organization (WHO) cut-off point for overweight, was considered high-risk. Being overweight or obese has been associated with an increased risk of developing hypertension in middle-aged men and women (Field et al., 2001). Participants who did not meet the minimal recommendation of 150 min of moderate-vigorous PA a week, as per WHO (WHO, 2010) and current Australian guidelines (Australian Department of Health, 2014), were deemed at risk. Consuming < 2 serves of fruit and/or < 3 serves of vegetables per day was defined as high-risk, based on cut-points previously used in studies involving population health surveillance (Ding et al., 2015b; Centre for Epidemiology and Research, 2008). Alcohol risk was defined as consuming > 14 drinks per week, an amount exceeding the Australian National Health and Medical Research Council's recommendations (NHMRC, 2009). Those who reported being current smokers (including daily and occasional smokers) were considered at risk. Risk of psychological distress was defined as the presence of high to very high levels of psychological distress (K10 score ≥ 22), as used in a previous study involving this cohort (Nguyen et al., 2017a).

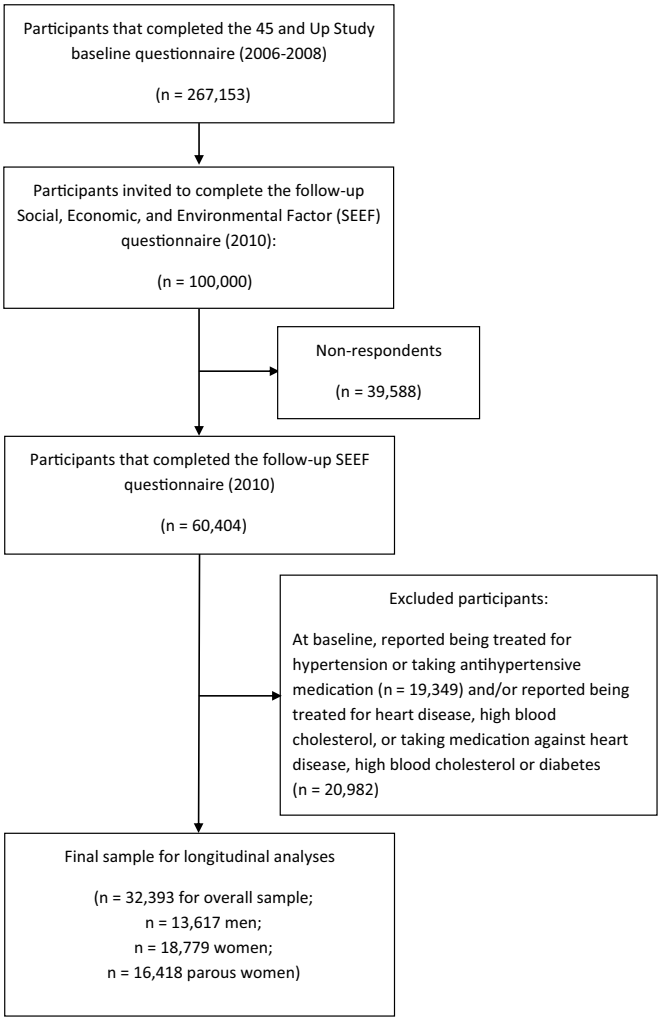

Fig. 1. Participant flow chart (45 and Up Study, 2006–2010).

To examine the combined influence of lifestyle risk factors, a lifestyle risk score (LRS) was calculated for each participant by summing up the number of lifestyle factors in the high-risk category. A combined score approach is a common approach (McAloney et al., 2013) and has been used previously by several prospective cohort studies examining associations between combined lifestyle risk factors and cardiovascular risk factors and outcomes (Banda et al., 2010; Chiuve et al., 2006; Myint et al., 2009; vanDam et al., 2008). The LRS was further categorised as: 0, 1, 2, and 3 to 6 (these scores were combined due to the small percentages of participants with 3 to 6 risk factors).

2.2.4. Covariates

Covariates were based on self-reported information from the baseline questionnaire, and included the following socio-demographic

characteristics: age (45–54, 55–64, 65–74, ≥75 years), sex, country of birth (Australia/New Zealand, Europe, Middle East, Asia, Canada/United State, Africa, other), educational attainment (university degree/higher, high school/trade apprenticeship/certificate/diploma, ≤10 years of schooling), area-level socio-economic status (quintiles based on the Socio-Economic Indexes For Area - Index of Relative Socio-Economic Disadvantage [SEIFA-IRSD; Australian Bureau of Statistics, 2008]); medical variables: family history of hypertension (yes/no), aspirin use (yes/no), omega 3 or fish oil use (yes/no); and follow-up time. In separate analyses conducted in women, additional covariates were included: oral contraceptive use (ever/never), current use of hormonal replacement therapy (yes/no), menopausal status (pre-menopausal, post-menopausal, not sure/irregular periods), and number of children given birth to (0, 1, 2, 3, ≥4). To further explore risk factors for women within the context of reproductive history, a sub-analysis involving parous women only was additionally adjusted for the following reproductive variables: mother's age for first child (years), lifetime breastfeeding duration (months), and hypertension during pregnancy (yes/no).

2.3. Statistical analysis

Baseline participant characteristics by sex were presented as means (standard deviation [SD]) or percentages. Differences in baseline characteristics between men and women were examined using student *t*-tests for continuous variables and chi-square tests for categorical variables. The association between individual lifestyle risk factors or the LRS and incident hypertension were examined using logistic regression. The lower-risk category for lifestyle factors and the LRS (LRS = 0) was chosen as the reference category. Odds ratios (ORs) with 95% confidence intervals (CIs) were estimated for unadjusted and multivariate-adjusted models in the overall sample, and separately in men and women. Individual lifestyle factors were mutually adjusted for each other. We tested for effect modification by age (< 65 years vs ≥65 years) and sex by fitting interaction terms with the LRS. Finally, sensitivity analyses were conducted separately in men and women to examine whether findings differed if lifestyle factors were considered as continuous variables rather than using specific cut-points. Analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY).

3. Results

Of 32,393 participants without hypertension at baseline, 5539 (17.1%) reported hypertension at follow-up (mean [SD]: 2.7 [0.9] years). Participants' socio-demographic and lifestyle characteristics at baseline are presented in Table 1. The mean age of participants at baseline was 58.3 (SD: 9.2) years and most (80%) were born in Australia/New Zealand. More than half (58%) of the sample were women, nearly a third (30.8%) had a university degree and nearly half (46.9%) reported a family history of hypertension. More than half (53.5%) of participants were overweight/obese, more than three-quarters (83%) were physically active (≥150 min/week), and less than half (42.8%) consumed ≥2 fruit and ≥3 vegetables/day. In addition, more than three-quarters (86%) consumed ≤14 drinks of alcohol/week, nearly two-thirds (60.3%) were never smokers, less than a tenth (6.7%) were current smokers, and the majority (94.6%) had a low to moderate risk of psychological distress. Overall, more than half (53.4%) had a lower-risk lifestyle (LRS = 0–1). Compared to men, women were on average younger and had a healthier lifestyle overall, and a higher proportion of women had completed ≤10 years of education. Among women, more than half (57.3%) were post-menopausal, and on average had more than two (mean: 2.3; SD: 1.4) children. Parous women breastfed an average of 16 (SD: 16) months during their lifetime.

Table 2 shows the unadjusted and adjusted ORs for the associations between six lifestyle risk factors, the LRS, and incident hypertension in the overall sample. In unadjusted models, high-risk categories for all six lifestyle risk factors were significantly associated with higher odds of incident hypertension. After adjustment for covariates, being overweight/obese, exercising < 150 min/week, consuming > 14 drinks of alcohol/week and being a current smoker remained significantly associated with higher odds of incident hypertension. In both unadjusted and adjusted models, the odds of incident hypertension increased with an increasing number of high-risk lifestyle risk factors. Participants in the highest LRS category (LRS = 3 to 6) had 2.58 (95% CI: 2.29, 2.90) the odds of developing hypertension compared with participants without any high-risk factors.

The unadjusted and adjusted ORs for incident hypertension by categories of lifestyle risk factors and LRS are also presented separately for men (Table 3) and women (Table 4). In men, high-risk categories for BMI, physical activity, fruit and vegetable intake, alcohol intake and smoking status were associated with higher odds of incident hypertension in unadjusted models. In adjusted models, being overweight/obese, exercising < 150 min/week and consuming > 14 drinks of alcohol/week remained significant. A larger number of high-risk factors was associated with higher odds of developing hypertension following covariate adjustment.

In women, high-risk categories for BMI, physical activity, alcohol intake and current smoking status were associated with higher odds of incident hypertension in unadjusted models. Similar to findings in men, these associations remained significant for BMI, physical activity and alcohol intake following adjustment for covariates. An increasing number of high-risk factors was associated with increased odds of developing hypertension. However, the pattern of association differed significantly between men and women (test for interaction $p < 0.003$).

In unadjusted analyses, all women-specific covariates were significantly associated with incident hypertension. These associations did not remain significant following covariate adjustment. In the sub-analysis involving parous women only, lifetime breastfeeding duration and high blood pressure during pregnancy remained significantly associated with lower and higher odds of hypertension, respectively, after adjustment for additional reproductive variables.

There was a significant interaction between the LRS and age categories ($p < 0.001$). The association between the LRS and incident hypertension was stronger in individuals aged < 65 years compared to those aged ≥65 years, especially among middle-aged men (Table 5). Sensitivity analyses conducted in separately in men and women showed that results were similar when lifestyle factors were examined as continuous variables rather than using cut-points.

4. Discussion

In this study following a large cohort of middle-aged and elderly adults for three years, being overweight/obese, a high weekly alcohol intake, and a low amount of physical activity per week were associated with higher odds of developing hypertension, in both men and women. A higher number of lifestyle risk factors was associated with higher odds of incident hypertension in both the overall sample and in separate analyses in men and women. A salient finding from this study was that a higher-risk lifestyle for hypertension seemed more detrimental in middle-aged than older adults, especially in men, highlighting the importance of lifestyle risk reduction among middle-aged men.

There is growing evidence supporting the importance of considering the combined effects of lifestyle risk factors on health. To date, several prospective studies have examined associations between combined lifestyle risk factors and adverse health outcomes, such as coronary heart disease (Chiuve et al., 2006; Stampfer et al., 2000), stroke (Kurth et al., 2006; Chiuve et al., 2008; Myint et al., 2009), sudden cardiac death (Chiuve et al., 2011), myocardial infarction (Akesson et al., 2007), diabetes (Hu et al., 2001), as well as cause-specific and all-cause mortality (Ford et al., 2011; Kvaavik et al., 2010; Loef and Walach, 2012; vanDam et al., 2008). In these studies, adherence to a healthy lifestyle was generally associated with better health outcomes. To our

Table 1
Baseline characteristics[a] of participants in the overall sample (n = 32,393) and according to sex (45 and Up Study, 2006–2010).

Variable	All (n = 32,393)	Men (n = 13,614)	Women (n = 18,779)
Mean (SD) follow-up time (years)	2.7 (0.9)	2.7 (0.9)	2.7 (0.9)
Age group[b] (%)	21.9	27.8	17.6
45–54 years	43.8 (n = 14,190)	38.0 (n = 5167)	48.0 (n = 9023)
55–64 years	34.3 (n = 11,105)	34.2 (n = 4662)	34.3 (n = 6443)
65–74 years	15.5 (n = 5027)	18.8 (n = 2554)	13.2 (n = 2473)
≥75 years	6.4 (n = 2071)	9.0 (n = 1231)	4.5 (n = 840)
Country of birth[b] (%) (missing n = 315; missing n = 160 for men and missing n = 155 for women)			
Australia/New Zealand	80.0 (n = 25,677)	78.5 (n = 10,562)	81.2 (n = 15,115)
Europe	14.4 (n = 4615)	16.1 (n = 2168)	13.1 (n = 2447)
Asia	2.5 (n = 817)	2.4 (n = 320)	2.7 (n = 497)
Other	3.1 (n = 969)	3.0 (n = 404)	3.0 (n = 565)
Highest education[b] (%) (missing = 416; missing n = 185 for men and missing n = 162 for women)			
University and higher	30.8 (n = 9859)	32.0 (n = 4292)	31.0 (n = 5567)
High school/trade apprenticeship/certificate/diploma	43.2 (n = 13,846)	48.9 (n = 6562)	39.1 (n = 7284)
≤10 years	26.0 (n = 8341)	19.2 (n = 2575)	29.9 (n = 5766)
Socio-economic status (SEIFA-IRSD)[c] (%) (missing = 87; missing n = 39 for men and missing n = 48 for women)			
Lowest quintile (most disadvantaged)	13.4 (n = 4340)	13.7 (n = 1853)	13.3 (n = 2487)
Second lowest quintile	26.8 (n = 8672)	26.6 (n = 3606)	27.0 (n = 5066)
Third lowest quintile	22.3 (n = 7190)	22.5 (n = 3054)	22.1 (n = 4136)
Second highest quintile	12.1 (n = 3916)	11.9 (n = 1612)	12.3 (n = 2304)
Highest quintile (least disadvantaged)	25.3 (n = 8188)	25.4 (n = 3450)	25.3 (n = 4738)
Overweight or obese (≥25 kg/m^2)[b] (missing n = 2012; missing n = 733 for men and missing n = 1279 for women)	53.5 (n = 16,265)	62.2 (n = 8014)	47.1 (n = 8251)
Physical activity level[b,d] (%) (missing = 723; missing n = 317 for men and missing n = 406 for women)			
< 150 min/week	17.0 (n = 5387)	17.7 (n = 2350)	16.5 (n = 3037)
≥150 min/week	83.0 (n = 26,283)	82.3 (n = 10,947)	83.5 (n = 15,336)
Usually consumes ≥2 serves of fruit/day and ≥3 serves of vegetables/day[b] (%) (missing = 582; missing n = 224 for men and missing n = 48 for women)	42.8 (n = 13,607)	30.3 (n = 4056)	51.8 (n = 9551)
Usually consumes ≤14 drinks/week[b] (%) (missing = 347; missing n = 142 for men and missing n = 274 for women)	86.0 (n = 27,508)	76.1 (n = 10,257)	93.2 (n = 17,251)
Smoking status[b] (%) (missing = 14; missing n = 4 for men and missing n = 10 for women)			
Never smoker	60.3 (n = 19,520)	54.2 (n = 7378)	64.7 (n = 12,142)
Previous smoker	33.0 (n = 10,685)	38.7 (n = 5266)	28.9 (n = 5419)
Current smoker	6.7 (n = 2174)	7.1 (n = 966)	6.4 (n = 1208)
Low to moderate risk of psychological distress (K10 score < 22)[b,e] (%) (missing = 2254; missing n = 832 for men and missing n = 1422 for women)	94.6 (n = 28,521)	95.4 (n = 12,192)	94.1 (n = 16,329)
LRS[b,f] (%)			
LRS = 0	17.2 (n = 5565)	9.1 (n = 1238)	23.0 (n = 4327)
LRS = 1	36.2 (n = 11,733)	30.3 (n = 4126)	40.5 (n = 7607)
LRS = 2	30.8 (n = 9967)	37.5 (n = 5108)	25.9 (n = 4859)
LRS = 3 to 6	15.8 (n = 5128)	23.1 (n = 3142)	10.6 (n = 1986)
Family history of hypertension[b] (%) (missing = 1; missing n = 0 for men, missing n = 1 for women)	46.9 (n = 15,196)	39.1 (n = 5328)	52.6 (n = 9868)
Oral contraceptive use (%) (missing n = 212)	–	–	87.2 (n = 16,198)
Hormonal replacement therapy use (%) (missing n = 249)	–	–	34.6 (n = 6404)
Menopausal status (%) (missing = 2)	–	–	
Pre-menopausal	–	–	21.0 (n = 3941)
Post-menopausal	–	–	57.3 (n = 10,760)
Irregular periods/not sure	–	–	21.7 (n = 4076)
Number of children (missing n = 74)	–	–	2.3 (1.4) (n = 18,705)
Mother's age for first child[g] (years) (missing n = 2454)	–	–	25.5 (5.0) (n = 16,325)
Lifetime breastfeeding duration[g] (months) (missing n = 2239)	–	–	15.7 (16.0) (n = 16,540)
High blood pressure during pregnancy[g] (%)	–	–	8.1 (n = 1515)

Abbreviations: IRSD = Index of Relative Socio-economic Disadvantage, K10 = Kessler Psychological Distress Scale, LRS = lifestyle risk score, SD = standard deviation, SEIFA = Socio-Economic Indexes For Areas.

[a] Data are presented as means (SD) or percentages (%).

[b] Significantly different from men (all $p < 0.01$) based on *t*-tests for continuous variables and chi-square tests for categorical variables.

[c] A SEIFA index based on disadvantage and derived from Australian census variables including low income, low educational attainment, unemployment, and dwelling without motor vehicles (Australian Bureau of Statistics, 2008).

[d] Physical activity was calculated as the sum of time spent on walking, moderate-intensity physical activity, and vigorous-intensity physical activity (weighted by two) in the past week (Australian Institute of Health and Welfare, 2003).

[e] The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks (Andrews and Slade, 2001). A K10 score < 22 represents a "low-to-moderate risk" of psychological distress.

[f] Derived from the total number of lifestyle risk factors in the "high-risk" category.

[g] In parous women only (n = 16,349).

knowledge, only three studies have examined the combined influence of lifestyle risk factors on hypertension in either women (Cohen et al., 2012; Forman et al., 2009) or men (Banda et al., 2010), with findings in line with those from our study. In a large 14- (Forman et al., 2009) and 26-year (Cohen et al., 2012) prospective cohort study of women from the Nurses' Health Study, and a prospective cohort study in men followed over 10 years, having a higher number of low-risk lifestyle factors was associated with a lower risk of self-reported hypertension (Banda et al., 2010). Individual lifestyle factors examined in these studies, half of which overlapped with those considered in our study,

Table 2
Unadjusted and adjusted odds ratios for incident hypertension by categories of lifestyle risk factors in the overall sample (n = 32,393; 45 and Up Study, 2006–2010).

Variable	Unadjusted odds ratios (95% CI)	Adjusted odds ratios[a] (95% CI)
Body mass index category		
< 25 kg/m^2	1.0 (reference)	1.0 (reference)
≥ 25 kg/m^2	2.0 (1.88, 2.13)	1.99 (1.85, 2.13)
Physical activity[b] level		
≥ 150 min/week	(Reference)	1.0 (reference)
< 150 min/week	1.22 (1.13, 1.32)	1.17 (1.07, 1.27)
Usual fruit and vegetable intake		
≥ 2 serves of fruit/day and ≥ 3 serves of vegetables/day	1.0 (reference)	1.0 (reference)
< 2 serves of fruit/day and/or < 3 serves of vegetables/day	1.09 (1.03, 1.16)	1.06 (0.99, 1.13)
Alcohol intake		
≤ 14 drinks/week	1.0 (reference)	1.0 (reference)
> 14 drinks/week	1.60 (1.48, 1.73)	1.58 (1.44, 1.73)
Smoking status		
Never smoker	1.0 (reference)	1.0 (reference)
Previous smoker	1.16 (1.09, 1.24)	1.06 (0.99, 1.14)
Current smoker	1.16 (1.03, 1.30)	1.15 (1.0, 1.31)
Psychological distress (K10) score[c]		
Low to moderate risk (K10 < 22)	1.0 (reference)	1.0 (reference)
High to very high risk (K10 ≥ 22)	1.21 (1.06, 1.37)	1.15 (0.99, 1.32)
LRS[d]		
0	1.0 (reference)	1.0 (reference)
1	1.36 (1.23, 1.49)	1.35 (1.22, 1.49)
2	1.73 (1.57, 1.91)	1.76 (1.59, 1.94)
3 to 6	2.37 (2.14, 2.63)	2.45 (2.20, 2.74)

Abbreviations: CI = confidence interval, kg = kilograms, K10 = Kessler Psychological Distress Scale, LRS = lifestyle risk score, m = meter.

[a] Adjusted for age group, sex, follow-up time, country of birth, education, socio-economic status (based on Socio-Economic Indexes for Areas –Index of Relative Socio-Economic Disadvantage), family history of hypertension, omega 3 or fish oil use, aspirin use and lifestyle risk factors (body mass index, physical activity level, fruit and vegetable intake, alcohol intake, smoking status, K10 score; mutually adjusted for each other). Due to missing data, the multivariate analysis including individual lifestyle risk factors was based on n = 26,747, and the multivariate analysis including the lifestyle risk index was based on n = 31,954.

[b] Physical activity was calculated as the sum of time spent on walking, moderate-intensity physical activity, and vigorous-intensity physical activity (weighted by two) in the past week (Australian Institute of Health and Welfare, 2003).

[c] The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks (Andrews and Slade, 2001). A K10 score < 22 represents a low to moderate risk of psychological distress.

[d] Derived from the total number of lifestyle risk factors in the "high-risk" category.

Table 3
Unadjusted and adjusted odds ratios for incident hypertension by categories of lifestyle risk factors in men (n = 13,614; 45 and Up Study, 2006–2010).

Variable	Unadjusted odds ratios (95% CI)	Adjusted odds ratios[a] (95% CI)
Body mass index category		
< 25 kg/m^2	1.0 (reference)	1.0 (reference)
≥ 25 kg/m^2	1.95 (1.76, 2.15)	1.97 (1.77, 2.21)
Physical activity[b] level		
≥ 150 min/week	1.0 (reference)	1.0 (reference)
< 150 min/week	1.13 (1.01, 1.26)	1.14 (1.01, 1.30)
Usual fruit and vegetable intake		
≥ 2 serves of fruit/day and ≥ 3 serves of vegetables/day	1.0 (reference)	1.0 (reference)
< 2 serves of fruit/day and/or < 3 serves of vegetables/day	1.14 (1.04, 1.26)	1.09 (0.97, 1.21)
Alcohol intake		
≤ 14 drinks/week	1.0 (reference)	1.0 (reference)
> 14 drinks/week	1.66 (1.51, 1.82)	1.62 (1.45, 1.81)
Smoking status		
Never smoker	1.0 (reference)	1.0 (reference)
Previous smoker	1.25 (1.14, 1.37)	1.08 (0.97, 1.20)
Current smoker	1.24 (1.05, 1.47)	1.16 (0.95, 1.41)
Psychological distress (K10) score[c]		
Low to moderate risk (K10 < 22)	1.0 (reference)	1.0 (reference)
High to very high risk (K10 ≥ 22)	1.22 (1.0, 1.50)	1.17 (0.94, 1.47)
LRS[d]		
0	1.0 (reference)	1.0 (reference)
1	1.19 (0.99, 1.44)	1.23 (1.02, 1.50)
2	1.60 (1.33, 1.91)	1.69 (1.40, 2.03)
3 to 6	2.39 (1.98, 2.87)	2.55 (2.10, 3.10)

Abbreviations: CI = confidence interval, kg = kilograms, K10 = Kessler Psychological Distress Scale, LRS = lifestyle risk score, m = meter.

[a] Adjusted for age group, follow-up time, country of birth, education, socio-economic status, family history of hypertension, aspirin use, omega 3 or fish oil use and lifestyle risk factors (body mass index, physical activity level, fruit and vegetable intake, alcohol intake, smoking status, K10 score; mutually adjusted for each other).

[b] Physical activity was calculated as the sum of time spent on walking, moderate-intensity physical activity, and vigorous-intensity physical activity (weighted by two) in the past week (Australian Institute of Health and Welfare, 2003).

[c] The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks (Andrews and Slade, 2001). A K10 score < 22 represents a low to moderate risk of psychological distress.

[d] Derived from the total number of lifestyle risk factors in the "high-risk" category.

included BMI (Banda et al., 2010; Cohen et al., 2012; Forman et al., 2009), physical activity (Banda et al., 2010; Cohen et al., 2012; Forman et al., 2009), cardiorespiratory fitness (Banda et al., 2010), alcohol intake (Banda et al., 2010; Cohen et al., 2012; Forman et al., 2009), smoking (Banda et al., 2010), a Dietary Approach to Stop Hypertension score (Cohen et al., 2012; Forman et al., 2009), non-narcotic analgesic use (Cohen et al., 2012; Forman et al., 2009), folic acid supplementation (Forman et al., 2009) and menopause (Cohen et al., 2012). As in our study, the strongest association was observed with BMI in all of these studies (Cohen et al., 2012; Forman et al., 2009; Banda et al., 2010).

Compared to these previous studies, our study is innovative in that it examined whether poor mental health was associated with incident hypertension. Although several prospective studies have reported a link between psychological factors and the risk of hypertension, findings from previous studies have been mixed (Meng et al., 2012; Rutledge and Hogan, 2002; Shinn et al., 2001). In our study, being at high risk of psychological distress was not associated with incident hypertension. Differences in findings between studies could be due to a range of methodological factors including differences in follow-up period, sample size, exposure variables and hypertension measurement. Additional longitudinal studies may help further elucidate any relationship between psychological distress and incident hypertension.

Extending previous evidence, our study compared findings between men and women. When considered individually, BMI, alcohol intake and physical activity level were significantly associated with incident hypertension in both men and women. These findings are not surprising as it has been previously shown that BMI (Gelber et al., 2007; Shuger et al., 2008), physical activity (Liu et al., 2017) and alcohol intake (Briasoulis et al., 2012) are important individual risk factors for hypertension in both sexes. However, after adjustment for confounders, there were no apparent associations with other lifestyle risk factors in separate analyses in men and women. Although the association between being a current smoker and developing hypertension achieved significance in the overall sample, it did not remain significant in separate analyses in men and women. Whilst smoking is a known risk

Table 4
Unadjusted and adjusted odds ratios for incident hypertension by categories of lifestyle risk factors in women (n = 18,779; 45 and Up Study, 2006–2010).

Variable	Unadjusted odds ratios (95% CI)	Adjusted odds ratios[a] (95% CI)
Body mass index category		
< 25 kg/m^2	1.0 (reference)	1.0 (reference)
≥ 25 kg/m^2	2.02 (1.85, 2.21)	1.98 (1.80, 2.17)
Physical activity[b] level		
≥ 150 min/week	1.0 (reference)	1.0 (reference)
< 150 min/week	1.33 (1.19, 1.48)	1.19 (1.06, 1.34)
Usual fruit and vegetable intake		
≥ 2 serves of fruit/day and ≥ 3 serves of vegetables/day	1.0 (reference)	1.0 (reference)
< 2 serves of fruit/day and/or < 3 serves of vegetables/day	0.99 (0.91, 1.08)	1.05 (0.96, 1.15)
Alcohol intake		
≤ 14 drinks/week	1.0 (reference)	1.0 (reference)
> 14 drinks/week	1.34 (1.14, 1.57)	1.50 (1.28, 1.77)
Smoking status		
Never smoker	1.0 (reference)	1.0 (reference)
Previous smoker	1.08 (0.98, 1.18)	1.07 (0.97, 1.19)
Current smoker	1.19 (1.0, 1.40)	1.15 (0.95, 1.39)
Psychological distress (K10) score[c]		
Low to moderate risk (K10 < 22)	1.0 (reference)	1.0 (reference)
High to very high risk (K10 ≥ 22)	1.17 (0.98, 1.40)	1.08 (0.89, 1.31)
Oral contraceptive use		
No	1.0 (reference)	1.0 (reference)
Yes	0.80 (0.70, 0.90)	0.90 (0.78, 1.04)
Hormonal replacement therapy use		
No	1.0 (reference)	1.0 (reference)
Yes	1.27 (1.17, 1.39)	1.04 (0.94, 1.15)
Menopausal status		
Pre-menopausal	1.0 (reference)	1.0 (reference)
Post-menopausal	1.43 (1.28, 1.60)	1.03 (0.88, 1.19)
Irregular periods/not sure	1.39 (1.22, 1.59)	1.20 (1.03, 1.40)
Number of children	1.11 (1.07, 1.15)	1.01 (0.98, 1.04)
Mother's age for first child[e]	0.97 (0.96, 0.97)	0.99 (0.98, 1.01)
Lifetime breastfeeding duration[e]	0.99 (0.99, 0.99)	0.99 (0.99, 0.99)
High blood pressure during pregnancy[e]		
No	1.0 (reference)	1.0 (reference)
Yes	2.52 (2.24, 2.84)	2.27 (1.98, 2.61)
LRS[d]		
0	1.0 (reference)	1.0 (reference)
1	1.43 (1.27, 1.62)	1.44 (1.28, 1.62)
2	1.82 (1.60, 2.06)	1.84 (1.62, 2.08)
3 to 6	2.09 (1.79, 2.43)	2.22 (1.91, 2.58)

Abbreviations: CI = confidence interval, kg = kilograms, K10 = Kessler Psychological Distress Scale, LRS = lifestyle risk score, m = meter.

[a] Adjusted for age group, follow-up time, country of birth, education, socio-economic status, family history of hypertension, aspirin use, omega 3 or fish oil use, lifestyle risk factors (body mass index, physical activity level, fruit and vegetable intake, alcohol intake, smoking status, K10 score; mutually adjusted for each other), current use of hormonal replacement therapy, oral contraceptive use, menopausal status and number of children given birth to. Additional covariates in parous women only: mother's age for first child, lifetime breastfeeding duration and high blood pressure during pregnancy.

[b] Physical activity was calculated as the sum of time spent on walking, moderate-intensity physical activity, and vigorous-intensity physical activity (weighted by two) in the past week (Australian Institute of Health and Welfare, 2003).

[c] The total K10 score is based on a 10-item questionnaire about anxiety and depression symptoms experienced in the last four weeks (Andrews and Slade, 2001). A K10 score < 22 represents a low to moderate risk of psychological distress.

[d] Derived from the total number of lifestyle risk factors in the "high-risk" category.

[e] In sub-analysis involving parous women only (n = 16,349).

factor for cardiovascular disease, its association with incident hypertension remains uncertain. Paradoxically, non- and previous smokers have been shown to have higher blood pressure compared to smokers (Green et al., 1986) and prolongation of smoking cessation has been associated with higher increases in blood pressure, compared with current smokers (Lee et al., 2001). The association between dietary intake and incident hypertension has been shown more consistently in previous studies (Dauchet et al., 2007; Lelong et al., 2017; Schulze et al., 2003). The lack of an association in this study could be due to self-reported intake not accurately reflecting true consumption of fruit and vegetables, as well as residual confounding from other important dietary factors such as sodium intake that could not be assessed in this study. In epidemiological studies, sodium intake is usually estimated using food frequency questionnaires. However, this method is faced with several challenges including being prone to underreporting. Although 24-hour urine collection is considered the gold standard method, but this imposes a high respondent burden in large population-based studies (McLean et al., 2017).

Gender differences were more apparent when lifestyle factors were examined in combination with the pattern of association significantly differing between men and women. A higher-risk lifestyle appeared more detrimental for developing hypertension in men than in women. In addition, our study found that the total number of lifestyle risk factors seemed more strongly associated with hypertension in middle-aged adults than older adults, especially in middle-aged men. The association in older men appeared weaker than that observed in older women. These findings concur with the well-recognised observation that there is a higher incidence of hypertension in aged-matched men compared to premenopausal women, however, after menopause, there is marked increase in women resulting in a higher incidence in women compared to men. A previous study has also found that older age attenuates the associations between several lifestyle risk factors and incident hypertension in women from the Nurses' Health Study I (Cohen et al., 2012). Physiologic changes associated with ageing, such as increased arterial stiffness, lower responsiveness of the sympathetic nervous system, and changes in sex hormones, may help to explain these findings (Cohen et al., 2012; Dubey et al., 2002). Despite a need for further studies examining potential sex differences and the moderating effects of age, these findings have important public health implications as they identify middle-aged men as a high-risk group for developing hypertension, and to a lesser extent middle-aged women, and highlight the need for prevention strategies that focus on the middle-aged population.

Middle age is a critical period for interventions as changes in blood pressure during middle age can have a significant impact on lifetime risk for cardiovascular disease. A study involving data pooled from seven epidemiologic cohort studies reported that individuals that maintain or lower their blood pressure to normal levels by 55 years of age have the lowest lifetime risk for cardiovascular disease, in comparison to those who experience an increase in blood pressure and have a higher lifetime risk for cardiovascular disease (Allen et al., 2012). Another significant finding from this study was that more than two thirds of men who developed hypertension in middle age were likely to experience a cardiovascular disease event by 85 years of age, again highlighting the importance of identifying prevention strategies for middle-aged men. Prevention efforts should also not only consider people with established hypertension but also those with lesser degrees of hypertension, as it has recently been shown that a considerable portion of cardiovascular disease burden attributable to hypertension is borne by people with pre-hypertension (Lawes et al., 2008).

Finally, a unique aspect of this study was the inclusion of a range of covariates specific to women, including those relating to reproductive history. In the sub-analysis involving parous women only, both lifetime breastfeeding duration and hypertension during pregnancy were significantly associated with incident hypertension. These findings are in agreement with previous studies. Indeed, there is emerging evidence that breastfeeding is associated with the incidence of hypertension and may offer other cardiovascular health benefits (Nguyen et al., 2017b), while high blood pressure during pregnancy has been linked to a higher

Table 5
Adjusted odds ratios for incident hypertension by categories of the lifestyle risk index stratified by sex and age (< 65 or ≥65 years; 45 and Up Study, 2006–2010).

Variable	Women (n = 18,565)		Men (n = 13,389)	
	< 65 years (n = 15,316)	≥65 years (n = 3249)	< 65 years (n = 9699)	≥65 years (n = 3690)
	AORs (95% CI)	AORs (95% CI)	AORs (95% CI)	AORs (95% CI)
LRS[a]				
0	1.0 (reference) (n = 3380)	1.0 (reference) (n = 896)	1.0 (reference) (n = 766)	1.0 (reference) (n = 445)
1	1.49 (1.30, 1.71) (n = 6147)	1.28 (1.04, 1.58) (n = 1386)	1.51 (1.15, 1.99) (n = 2749)	0.99 (0.75, 1.31) (n = 1317)
2	1.93 (1.67, 2.23) (n = 4035)	1.45 (1.15, 1.83) (n = 758)	2.17 (1.66, 2.83) (n = 3730)	1.21 (0.92, 1.60) (n = 1288)
3 to 6	2.33 (1.97, 2.75) (n = 1754)	1.51 (1.06, 2.13) (n = 209)	3.55 (2.72, 4.65) (n = 2454)	1.41 (1.04, 1.92) (n = 640)

Abbreviations: AOR = adjusted odds ratio, CI = confidence interval, kg = kilograms, K10 = Kessler Psychological Distress Scale, LRS = lifestyle risk score.
[a] Derived from the total number of lifestyle risk factors in the "high-risk" category.

risk of subsequent hypertension and cardiovascular disease (Grandi et al., 2017; Magnussent et al., 2009).

4.1. Strengths and limitations

The main strengths of this study include a large population sample, a prospective design, the use of validated measures, and a wide range of covariates considered. Sensitivity analyses were conducted with continuous variables for lifestyle risk factors. This study presents some limitations including a short follow-up time and reliance on self-reported data, which may introduce bias. However, hypertension and lifestyle risk factors were assessed using mostly validated measures. The possibility of residual confounding could not be excluded despite the inclusion of multiple covariates. For example, important dietary factors such as sodium intake could not be assessed from the limited number of short dietary questions. While it is possible that this study sample may not be representative of the general population, a previous study comparing 45 and Up Study participants to participants from a representative NSW Population Health Survey reported similar estimates for exposure-outcome associations, despite different risk factor prevalence (Mealing et al., 2010). The minimal information available about SEEF non-respondents may affect the generalisability of findings.

5. Conclusion

Findings from this study are of public health significance as hypertension is one of the most important preventable causes of premature deaths worldwide. Results from this study highlight the importance of adopting an overall healthy lifestyle, particularly in middle-aged men who were identified as a higher risk group. The reduction of lifestyle risk factors is an essential component of prevention strategies aimed at reducing the incidence of hypertension and preventing subsequent cardiovascular disease.

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Conflicts of interest

None declared.

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