Incidence and risk factors of isolated systolic and diastolic hypertension: a 10 year follow-up of the Tehran Lipids and Glucose Study

Samaneh Asgari, Davood Khalili, Yadollah Mehrabi, Sara Kazempour-Ardebili, Fereidoun Azizi and Farzad Hadaegh

Prevention of Metabolic Disorders Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran; Department of Epidemiology, School of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran; Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abstract

The objective of this study is to examine the incidence and risk factors of isolated systolic hypertension (ISH) and isolated diastolic hypertension (IDH) in a Middle Eastern population, during a median follow-up of 9.6 years. In total, 8573 subjects without hypertension, cardiovascular disease and known diabetes were recruited into the study. To calculate the incidence of ISH, those with diastolic blood pressure (DBP) ≥ 90 mmHg during follow-up, and for calculating IDH those with systolic blood pressure (SBP) ≥ 140 mmHg during follow-up, were excluded. During follow-up, 235 new cases of ISH were identified, with a crude incidence rate of 5.7/1000 person-years; the corresponding values for IDH were 470 and 10.9/1000 person-years. Using backward stepwise Cox regression analysis, older age, baseline SBP and body mass index were related to incident ISH. Regarding IDH, younger age, baseline DBP and waist circumference were associated with higher risk, whereas female gender and being married were associated with lower risk (all p < 0.05). The C-statistics for the prediction model were 0.91 for ISH and 0.76 for IDH. In conclusion, after a decade of follow-up of this Iranian population, we found an incidence of about 0.5% and 1% per year for ISH and IDH, respectively.

Introduction

Globally, about 40% of adults aged ≥ 25 years develop hypertension. The prevalence of hypertension for the Eastern Mediterranean region is currently reported at about 40% in both genders (42% in men and 40% in women).[1] The national prevalence of hypertension among Iranian adults, aged 25–64 years, has been reported to be 26.6% (24.7% in men and 28.6% in women).[2] Furthermore, the total incidence rate of hypertension in the urban population of Iran was reported at about 30/1000 person-years.[3] Hypertension is directly responsible for heart disease, stroke and kidney problems, as well as premature mortality. According to the World Health Organization, hypertension is responsible for about 45% and 51% of deaths due to ischaemic heart disease and stroke, respectively.[1]

Isolated systolic hypertension (ISH) is a subtype of hypertension that is defined as elevated systolic blood pressure (SBP ≥ 140 mmHg) and normal diastolic blood pressure (DBP < 90 mmHg).[4] Previous studies have shown that ISH is highly dependent on age and it is more prevalent in older adults.[4–7] Results from the National Health and Nutrition Examination Survey showed that the total prevalence of untreated ISH between 1999 and 2010 was 9.4%. However, their results also indicate that the overall prevalence of ISH decreased significantly, by 1.8% from 1999–2004 to 2005–2010; in addition, it was reported that the prevalence of ISH decreased among older and female individuals during this period.[4] Recently, a study conducted in the Middle East region reported that in a middle-aged population, ISH increased the risk of cardiovascular disease (CVD) by 52%, whereas in the older population, ISH increased the risks of both CVD and CVD-related mortality.[6]

Isolated diastolic hypertension (IDH) is clinically defined as normal SBP (<140 mmHg) and high DBP (≥ 90 mmHg). As reported by the Framingham Heart Study, IDH is more common among young adults and more frequent in men, smokers and those with high body mass index (BMI).[8] They also reported that participants with IDH were 23 times more likely to develop hypertension during 10 years of follow-up. According to one study conducted in an urban Iranian population, IDH increased the risk of total death in...
middle-aged and elderly participants, but it only increased the risk of CVD mortality in older individuals.[6]

To the best of our knowledge, the incidence of ISH and IDH and their potential risk factors have been reported in one study, with only 3 years of follow-up.[9] The long-term population-based cohort of the Tehran Lipids and Glucose Study (TLGS) has provided us with this unique opportunity to estimate the incidence of ISH together with IDH and their potential risk factors after nearly a decade of follow-up.

Materials and methods

Study population

In brief, TLGS is a long-term prospective population-based study carried out on a representative sample of Tehranian residents with the aim of determining the prevalence and incidence of non-communicable disease risk factors. The gender and age distribution of the TLGS participants in this district at baseline were representative of the general population at the time of recruitment.[10]

_data collection_

Data collection is ongoing, at 3 year intervals, for at least 20 years. Details of the TLGS protocol have been published elsewhere.[10] TLGS has two main parts: a cross-sectional study (phase I: 1999–2001) and a prospective ongoing follow-up study during three frequent examination phases to date (phase II: 2002–2005, phase III: 2005–2008 and phase IV: 2008–2011).

In total, 12,808 individuals, aged ≥20 years, were enrolled in the first (n = 10,368) and second (n = 2440) examination phases. For the current study, participants with prevalent hypertension (n = 2660) or prevalent CVD (n = 122) and those with drug-treated diabetes (n = 119) were excluded. Participants with missing data for baseline covariates (n = 1334) and those lost to follow-up (n = 3175) were also excluded. Furthermore, after excluding participants with DBP ≥ 90 mmHg in any of the follow-up phases and those using antihypertensive drugs before incident ISH (n = 824), 4574 participants with a median 9.57 years of follow-up were considered as the ISH study population. The IDH study population was structured by excluding those with SBP ≥ 140 mmHg at any follow-up phase or use of antihypertensive medication before incident IDH (n = 589). Thus, 4809 participants with a median follow-up of 9.62 years were considered for IDH analysis in the current study (Figure 1).

The Ethics Committee of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, approved the design of the TLGS, and all participants provided written informed consent.

Data collection

Trained interviewers performed a face-to-face private interview to collect baseline information, including demographic information, cigarette smoking, and educational, medical and drug history. Anthropometric measurements were taken using the standard protocols.

Weight was measured while participants were minimally dressed, wearing no shoes, using digital scales (Seca 707; range 0.1–150 kg), and documented to the nearest 100 g. Height was measured using a tape meter, as standing height without shoes while their shoulders were in a normal position. Waist circumference (WC) was measured at the umbilical level with a tape meter, over light clothing, with no pressure on the body surface. WC measurements were verified to the nearest 0.1 cm without applying any pressure. To measure wrist circumference, individuals were asked to hold up the anterior surface of their wrist and the measurement was taken with a precision of 0.1 cm using a tape meter with no pressure over it. Hip circumference was also measured over light clothing at the widest portion. Body mass index (BMI) was calculated by dividing the weight (kilograms) by the square of height (metres).

Systolic and diastolic blood pressure (SBP and DBP) were calculated based on the average of two measurements taken in a seated position, from the right arm. A standard mercury sphygmomanometer was used to evaluate individuals’ blood pressure. Blood samples were collected after 12–14 h overnight fasting, between 07:00 and 09:00 h, during physical examinations. Descriptions of biochemical measurements for total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), fasting plasma glucose (FPG) and 2 hour post-challenge plasma glucose (2hPCPG) have been reported elsewhere.[10]

Definition of terms

The abbreviated prediction equation, presented by the Modification of Diet in Renal Disease (MDRD) study, was used to calculated the estimated glomerular filtration rate (eGFR).[11] Participants who reported smoking cigarettes or pipes, either daily or occasionally, were defined as current smokers. Educational level was categorized into three groups: <6 years, 6–11 years and ≥12 years (duration of education). Marital status was categorized as married or single (including single, divorced or widowed). Hypertension was defined as the...
SBP ≥ 140 mmHg or the DBP ≥ 90 mmHg or using any anti-hypertensive drugs.

**Statistical analysis**

Baseline characteristics of responders (those with complete data) and non-responders (those with missing data of covariates in either phase I or II or loss to follow-up) were described as mean ± SD values for continuous and as frequencies (%) for categorical variables. (Supplementary Table 1) For covariates with a skewed distribution (e.g. TG), the median (interquartile range) was reported. Comparison of baseline characteristics between those with incident ISH or IDH and the follow-up compared with non-event cases was done by the Student’s t test for continuous variables, the chi-squared test for categorical variables and the Mann–Whitney U statistic for skewed and ordered variables. The incidence rate of ISH and IDH, with 95% confidence interval (CI), was calculated by dividing the number of new cases of ISH and IDH by person-years at risk for each gender, age category (20–39 years, 40–59 years and ≥60 years) and the whole population, separately.

Cox proportional hazard regression was carried out using the backward stepwise selection method considering all possible covariates: age (years), FPG (mmol/l), eGFR (ml/min/1.73 m²), TG (mmol/l), HDL-C (mmol/l), TC (mmol/l), SBP (mmHg), DBP (mmHg), WC (cm),
wrist circumference (cm), hip circumference (cm), BMI (kg/m²), 2h-PCPG (mmol/l), smoking status (yes/no), educational level (<6 years as reference, 6–11 years, ≥12 years), being married (yes/no) and gender (women vs men), with \( p < 0.2 \) for enter and \( p > 0.1 \) for remove.

Event date was considered as the date of incident ISH or IDH. Censoring was defined as leaving the residential area, death, loss to follow-up or end of follow-up. The event date for participants with incident ISH was defined as the mid-time between the date of the follow-up appointment at which the ISH was detected for the first time and the latest follow-up visit before the diagnosis; for those with a negative event (censored subjects), the survival time was defined as the difference between the first and the last observation dates. A similar approach was applied to define IDH incidence and related survival time. In addition, we analysed gender interactions between ISH/IDH with potential risk factors in a multivariable model using the likelihood ratio test, and no interaction was observed between gender and potential risk factors. Therefore, to reach more statistical power, all analyses were performed in pooled datasets. The proportionality assumption of the multivariable Cox regression was evaluated using Schoenfeld’s global test of residuals and all proportionality hypotheses were appropriate. Harrell’s C index was used to check the discrimination ability of the models. A value of 1 indicates perfect discrimination and a value of 0.5 is no better than chance.[12] All analyses were conducted using STATA version 12 SE (StataCorp, TX, USA) and a two-tailed \( p \) value <0.05 was considered significant.

**Results**

**Characteristics of subjects with isolated systolic and diastolic hypertension**

Table 1 shows a comparison of baseline characteristics of the study population, with and without incident ISH/IDH. Participants with incident ISH were older, and had higher FPG, 2h-PCPG, TC, TG, SBP, DBP, WC, wrist circumference and BMI compared to individuals free of ISH at the end of follow-up (\( p < 0.05 \)); more of them were female and they also had lower educational levels and lower eGFR.

Subjects with incident IDH had higher FPG, 2h-PCPG, TC, TG, SBP, DBP, BMI, WC, wrist and hip circumference, compared to those without IDH. HDL-C level was lower in IDH cases. No statistically significant differences were observed in the frequencies of lipid medication, smoking, marital status, education and menopause between participants with and without IDH.

**Incidence of isolated systolic and diastolic hypertension**

During a median 9.57 year follow-up (interquartile range 8.74–10.64 years) of 4574 eligible participants, aged ≥20 years (2666 women and 1908 men), 235 new cases of ISH were identified (122 women and 113 men). The crude incidence rate (95% CI) of ISH in the total population was 5.7 (5.0–6.5) per 1000 person-years of follow-up. The highest incidence of ISH among age categories was observed in the older population (≥60 years), at 37.5 (30.6–46.0) per 1000 person-years, compared to younger adults (aged 20–39 years), at 0.8 (0.5–1.3) per 1000 person-years of follow-up.

In the current study population, 470 new cases of IDH (262 men and 208 women) were identified. In the total population, the crude incidence rate (95% CI) of IDH was 10.9 (10.0–12.0) per 1000 person-years. The incidence of IDH was higher in the middle-aged subjects (40–59 years), at 13.67 (11.8–15.8) per 1000 person-years, and a lower rate was observed in the population aged ≥60 years, at 6.4 (3.8–10.9) per 1000 person-years of follow-up (Table 2).

In addition, among the study population, 1574 new cases of hypertension were identified (802 women and 772 men); the corresponding crude incidence rate (95% CI) was 33.63 (32.0–35.3) per 1000 person-years. Furthermore, 326 new cases of both high SBP and DBP (i.e. SBP ≥140 mmHg and DBP ≥90 mmHg, and not using antihypertensive medication) (156 women and 168 men) were identified; the corresponding crude incidence rate (95% CI) was 6.3 (5.6–7.0) per 1000 person-years.

**Backward stepwise Cox regression analysis**

All associated covariates related to incident ISH on multivariable analysis are shown in Table 3. Age [hazard ratio (HR) 1.07, 95% CI 1.06–1.08] and SBP (HR 1.11, 95% CI 1.09–1.24) were significant risk factors of developing ISH. Increasing BMI (HR 1.04, 95% CI 1.0–1.07) showed a significant risk and increasing 2h-PCPG showed a 3% increased risk of ISH, which approached statistical significance (\( p = 0.08 \)). Considering the discrimination power, the ISH model had a C index of 91%.

Regarding IDH, increasing age had a protective effect (HR 0.98, 95% CI 0.97–0.99), while high DBP (HR 1.12, 95% CI 1.10–1.14) and high WC (HR 1.04, 95% CI 1.03–1.05) were also found to be strong risk factors. Female gender had a 34% lower risk of incident IDH compared with men (HR 0.66 women vs men, 95% CI 0.53–0.82, \( p < 0.001 \)). We found that married participants were at lower risk of incident IDH, compared with single ones.
Table 1. Comparison of baseline characteristics of subjects who did and did not develop isolated systolic hypertension (ISH) and isolated diastolic hypertension (IDH) after 9.68 years of follow-up.

|                  | Non-ISH (n = 4339) | ISH (n = 255) | p     | Non-IDH (n = 4339) | IDH (n = 470) | p     |
|------------------|--------------------|---------------|-------|--------------------|---------------|-------|
| **Age (years)**  | 37.45 ± 11.48      | 55.46 ± 11.37 | <0.001| 37.45 ± 11.48      | 38.24 ± 10.1  | 0.15  |
| eGFR (ml/min/1.73 m²) | 73.95 ± 11.47      | 66.62 ± 10.21 | <0.001| 73.95 ± 11.47      | 73.07 ± 11.22 | 0.11  |
| FPG (mmol/l)     | 4.99 ± 0.77        | 5.52 ± 1.56   | <0.001| 4.99 ± 0.77        | 5.10 ± 0.88   | 0.004 |
| 2h-PCPG (mmol/l) | 5.92 ± 2.23        | 7.37 ± 3.87   | <0.001| 5.92 ± 2.25        | 6.22 ± 2.43   | 0.006 |
| TC (mmol/l)      | 5.14 ± 1.11        | 5.7 ± 1.20    | <0.001| 5.14 ± 1.11        | 5.26 ± 1.01   | 0.02  |
| TG (mmol/l)      | 1.4 ± 1.11         | 1.75 ± 1.38   | <0.001| 1.40 ± 1.11        | 1.78 ± 1.38   | <0.001|
| HDL-C (mmol/l)   | 1.09 ± 0.28        | 1.08 ± 0.26   | 0.59  | 1.09 ± 0.28        | 1.02 ± 0.25   | <0.001|
| SBP (mmHg)       | 110.19 ± 10.63     | 125.7 ± 8.92  | <0.001| 110.19 ± 10.63     | 116.07 ± 9.80 | <0.001|
| DBP (mmHg)       | 72.83 ± 7.86       | 76.58 ± 7.64  | <0.001| 72.83 ± 7.86       | 79.56 ± 7.90  | <0.001|
| WC (cm)          | 85.1 ± 11.29       | 92.19 ± 10.38 | <0.001| 85.10 ± 11.29      | 90.88 ± 10.71 | <0.001|
| Wrist circumference (cm) | 16.49 ± 1.30 | 17.11 ± 1.22 | <0.001| 16.49 ± 1.29       | 17.08 ± 1.20  | <0.001|
| Hip circumference (cm) | 99.78 ± 8.76 | 100.57 ± 8.58 | 0.18  | 99.78 ± 8.76       | 102.38 ± 8.73 | <0.001|
| eGFR (ml/min/1.73 m²) | 73.95 ± 11.47      | 66.62 ± 10.21 | <0.001| 73.95 ± 11.47      | 73.07 ± 11.22 | 0.11  |
| BMI (kg/m²)      | 25.87 ± 4.32       | 37.45 ± 11.48 | <0.001| 25.87 ± 4.32       | 37.45 ± 11.48 | <0.001|
| Gender, female   | 2544 (58.9)        | 59 (1.4)      | 0.04  | 2544 (58.9)        | 679 (15.6)    | 0.19  |
| Lipid medication, yes | 3535 (81.5) | 59 (1.4)      | 0.33  | 3535 (81.5)        | 679 (15.6)    | 0.68  |
| Current smoking, yes | 679 (15.6) | 33 (14.0)     | 0.51  | 679 (15.6)         | 77 (16.4)     | 0.83  |
| Marital status, married | 3535 (81.5) | 208 (44.3)    | 0.83  | 3535 (81.5)        | 208 (44.3)    | 0.83  |

Data are shown as mean ± SD for continuous variables (p value calculated with the t test), n (%) for categorical variables (p value according to the chi-squared test) or median (interquartile range) for triglycerides (TG) (p value according to the Mann–Whitney U test).

Table 2. Isolated systolic and diastolic hypertension (ISH and IDH) incidence per 1000 person-years.

| Age (years) | No. at risk | No. of events | Follow-up (person-years) | Incidence (95% CI) (/1000 person-years) |
|------------|-------------|---------------|--------------------------|-----------------------------------------|
| ISH        |             |               |                          |                                         |
| 20–39      | 2772        | 21            | 25,745                   | 0.8 (0.5–1.3)                            |
| 40–59      | 1474        | 121           | 13,004                   | 9.3 (7.8–11.1)                           |
| >60        | 328         | 93            | 2,478                    | 37.5 (30.6–46.0)                         |
| Total      | 4574        | 235           | 41,227                   | 5.7 (5.0–6.5)                            |
| IDH        |             |               |                          |                                         |
| 20–39      | 3023        | 272           | 27,314                   | 9.9 (8.8–11.2)                           |
| 40–59      | 1537        | 184           | 13,461                   | 13.7 (11.8–15.8)                         |
| >60        | 249         | 14            | 2,175                    | 37.45 ± 11.48                           |
| Total      | 4809        | 470           | 42,950                   | 10.9 (10.0–12.0)                         |

*Crude incidence rate (95% confidence interval calculated using Fisher’s exact test.

Table 3. Multivariate hazard ratios (HRs) and 95% confidence intervals (CIs) from the backward stepwise approach.

|            | HR (95% CI) | p     | C-index |
|------------|------------|-------|---------|
| ISH        | 1.07       | <0.001| 0.91    |
| SBP        | 1.11       | <0.001| 0.91    |
| BMI        | 1.04       | 0.036 | 0.91    |
| 2h-PCPG    | 1.03       | 0.08  | 0.91    |
| IDH        | 1.04       | <0.001| 0.91    |
| Marital status, married | 1.04 | 0.036 | 0.91 |
| Gender, women | 1.04 | 0.036 | 0.91 |
| HDL-C      | 1.07       | 0.07  | 0.91    |

Table 4. Factors associated with incident ISH and IDH.

**Discussion**

During a decade’s follow-up of our Middle Eastern population, we found that 0.5% and 1% of participants developed ISH and IDH, respectively, per year. Among non-modifiable risk factors, being older was a significant risk factor for ISH incidence, while it was shown to be a protective factor for IDH. Also, being female and being married reduced the risk of IDH by about 33% and 28%, respectively. General adiposity, as manifested by BMI, and central obesity, as shown by WC, were significantly associated with incident ISH and IDH, respectively.

The incidence of ISH in this study was approximately 50% lower than in a Taiwanese study (5.7 vs 11.8 per 1000-person-years, respectively); however, our finding for incident IDH was almost two times higher than in a Taiwanese study (10.94 vs 6.25 per 1000-person-years, respectively).[9] This may be a result of differences in genetic predisposition, nutritional status, individuality, assessment procedure methodologies and different durations of exposure to ISH and IDH risk factors in various populations.

Considering the association between age and incident ISH and IDH, our findings are similar to those reported in different longitudinal studies looking at ethnic (HR 0.72, 95% CI 0.54–0.95). A high HDL-C reduced the risk of incident IDH by 33%, with borderline significance (p = 0.07). With respect to the discrimination power, IDH model had a C index of 76%.
differences among Americans and Asians, which reported that the incidence of ISH and IDH varies with age.[8,9] ISH is believed to be a complication of the ageing process and is mostly related to structural and functional changes of the vessel walls[13–15]; an increase in arterial stiffness causes elevated pulse pressure, with increased SBP and decreased DBP. Elevated SBP increases end-systolic stress and leads to cardiac hypertrophy,[16] whereas decreased DBP, by impairment of coronary perfusion, leads to myocardial ischaemia.[17] Furthermore, IDH is associated with elevations in the vascular resistance of the arteriolar sector and not ageing problems of the vessel walls. Both vascular resistance and arterial stiffness increase after middle age. While measurements of cardiac output and blood pressure show increased vascular resistance with ageing, total peripheral resistance is only slightly increased in older subjects with ISH compared with age- and gender-matched normotensive control subjects, indicating that vascular resistance is not the main factor in the rise in SBP after the age of 60 years. In our study, the switching of the incident IDH to ISH with age is a finding in agreement with the relative domination of vascular resistance with large changes in arterial stiffness with age.[9,18]

We found that female gender had a protective effect on IDH incidence but not on ISH incidence. These findings are in agreement with the Framingham Heart Study,[8] which showed that female gender reduces the risk of developing IDH.

Our results show that general obesity increased the risk of incident ISH and abdominal obesity was associated with an increased risk of IDH incidence. This finding does not concur with the Framingham Heart Study, which reported that baseline BMI is only a predictor of incident IDH.[8] Obesity is associated with high insulin and leptin levels, which increase sympathetic nervous system activity and produce elevated vasoconstriction, chronotropy and anti-natriuresis, leading to hypertension. Previous findings show a positive association between salt intake and blood pressure with increasing BMI and WC.[19] During a 6 year follow-up, we showed that WC among women was a significant risk factor for incident hypertension.[3] Results of previous studies differ regarding the association between general and central adiposity measurements with incident hypertension in different populations. Some researchers have reported a higher impact of BMI,[20–22] others have reported that central obesity has a greater effect,[3,22] while many studies highlight the absence of any influence of anthropometric measurements on the prediction of hypertension.[20,23–25]

In a meta-analysis including 15 prospective longitudinal studies of different populations, baseline SBP and DBP were found to predict the incidence of hypertension.[26] Our results also showed that baseline SBP and DBP increased the risk of developing ISH and IDH, by 11% and 12%, respectively.

We also found that incident IDH was linked to marital status. This result is completely in agreement with the results of a study of Swedes,[27] which demonstrated that married couples were at lower risk of developing hypertension. We hypothesize that this difference may be due to changes in a person’s lifestyle and their individual and social behaviours.

The strengths of this study include the large population-based sample of adults with long-term follow-up, and the use of real measurements of variables rather than self-reported data. We also report several baseline variables as potential risk factors of incident ISH/IDH. However, some limitations of this study need to be mentioned. First, some important risk factors for ISH/IDH, such as nutritional data, were not measured, despite their importance. However, it is difficult to assess nutritional status with adequate precision.[28] Secondly, owing to the large sample size, minor significant differences in baseline characteristics between participants and non-participants were highlighted that were not clinically important. However, regarding the higher age and BMI of participants versus non-participants, we may have over-estimated the incidence of ISH in our population. Finally, we conducted this study on an Iranian sample population and further studies on other populations are needed to check model application status.

In conclusion, in a decade-long follow-up of this Middle Eastern population, about 0.5% and 1% of our participants were found to develop ISH and IDH, respectively, annually. Female gender and being married were associated with a lower risk of developing IDH. Among modifiable risk factors, the role of general and central adiposity in the development of these phenotypes should be emphasized.

Acknowledgements

We express appreciation to the participants of district 13, Tehran, for their enthusiastic support. The authors also wish to acknowledge Mrs Niloofar Shiva for critical editing of the English grammar and syntax of the manuscript.

Declaration of interest

No potential conflict of interest was reported by the authors.

Funding information

This study was supported by the National Research Council of the Islamic Republic of Iran [grant no. 121].
References

1. World Health Organization. A global brief on hypertension. Geneva: WHO; 2013; http://www.who.int/cardiovascular_diseases/publications/global_brief_hypertension/en/(Access at 10 March 2015).

2. Esteghamati A, Meysamie A, Khalilzadeh O, Rashidi A, Haghazali M, Asgari F, et al. Third national Surveillance of Risk Factors of Non-Communicable Diseases (SuRFNCD-2007) in Iran: methods and results on prevalence of diabetes, hypertension, obesity, central obesity, and dyslipidemia. BMC Public Health. 2009;9:167.

3. Bozorgmanesh M, Hadaegh F, Mehrabi Y, Azizi F. A point-score system superior to blood pressure measures alone for predicting incident hypertension: Tehran Lipid and Glucose Study. J Hypertens. 2011;29:1486–493.

4. Liu X, Rodriguez CJ, Wang K. Prevalence and trends of isolated systolic hypertension among untreated adults in the United States. J Am Soc Hypertens. 2015;9:197–205.

5. Chobanian AV. Isolated systolic hypertension in the elderly. N Engl J Med. 2007;357:789–796.

6. Lotfaliany M, Akbarpour S, Mozafary A, Boloukat RR, Azizi F, Hadaegh F. Hypertension phenotypes and incident cardiovascular disease and mortality events in a decade follow-up of a Middle East cohort. J Hypertens. 2015;33:1153–1161.

7. Yano Y, Stamler J, Garside DB, Daviglus ML, Franklin SS, Carnethon MR, et al. Isolated systolic hypertension in young and middle-aged adults and 31-year risk for cardiovascular mortality: the Chicago Heart Association Detection Project in Industry study. J Am Coll Cardiol. 2015;65:327–335.

8. Franklin SS, Pio JR, Wong ND, Larson MG, Leip EP, Vasan RS, et al. Predictors of new-onset diastolic and systolic hypertension: the Framingham Heart Study. Circulation. 2005;111:1121–1127.

9. Yeh C-J, Pan W-H, Jong Y-S, Kuo Y-Y, Lo C-H. Incidence and predictors of isolated systolic hypertension and isolated diastolic hypertension in Taiwan. J Formos Med Assoc. 2001;100:668–675.

10. Azizi F, Ghanbarian A, Momenan AA, Hadaegh F, Mirmirm P, Hedayati M, et al. Tehran Lipid and Glucose Study Group. Prevention of non-communicable disease in a population in nutrition transition: Tehran Lipid and Glucose Study phase II. Trials 2009;10:15.

11. Levey AS, Greene T, Kusek JW, Beck GJ. An simplified equation to predict glomerular filtration rate from serum creatinine. J Am Soc Nephrol. 2000;11:155A.

12. Pencina MJ, D’Agostino RB. Overall C as a measure of discrimination in survival analysis: model specific population value and confidence interval estimation. Stat Med. 2004;23:2109–2123.

13. Franklin S. The pathobiology of isolated systolic hypertension. Hypertens Riesgo Vasc. 2010;27:23–26.

14. O’Rourke M. Arterial stiffness, systolic blood pressure, and logical treatment of arterial hypertension. Hypertension. 1990;15:339–347.

15. Pinto E. Blood pressure and ageing. Postgrad Med J. 2007;83:109–114.

16. Assmann G, Cullen P, Evers T, Petzinna D, Schulte H. Importance of arterial pulse pressure as a predictor of coronary heart disease risk in PROCAM. Eur Heart J. 2005;26:2120–2126.

17. Stehouwer C, Henry R, Ferreira I. Arterial stiffness in diabetes and the metabolic syndrome: a pathway to cardiovascular disease. Diabetologia. 2008;51:527–539.

18. Franklin SS, Gustin W, Wong ND, Larsson MG, Weber MA, Kannel WB, et al. Hemodynamic patterns of age-related changes in blood pressure: the Framingham Heart Study. Circulation. 1997;96:308–315.

19. Nizal Sarrafa-zadegan M, Zahra Abdollahi M. Is the association between salt intake and blood pressure mediated by body mass index and central adiposity? Arch Iran Med. 2013;16:167.

20. Dalton M, Cameron A, Zimmet P, Shaw J, Jolley D, Dunstan D, et al. Waist circumference, waist–hip ratio and body mass index and their correlation with cardiovascular disease risk factors in Australian adults. J Intern Med. 2003;254:555–563.

21. Nyamadorj R, Qiao Q, Süderberg S, Pitkäniemi J, Zimmet P, Shaw J, et al. Comparison of body mass index with waist circumference, waist-to-hip ratio, and waist-to-hip ratio as a predictor of hypertension incidence in Mauritius. J Hypertens. 2008;26:866–870.

22. Sakurai M, Miura K, Takamura T, Ota T, Ishizaki M, Morikawa Y, et al. Gender differences in the association between anthropometric indices of obesity and blood pressure in Japanese. Hypertens Res. 2006;29:75–80.

23. Hsieh SD, Muto T. Metabolic syndrome in Japanese men and women with special reference to the anthropometric criteria for the assessment of obesity: proposal to use the waist-to-height ratio. Prev Med. 2006;42:135–139.

24. Ito H, Nakasuga K, Oshima A, Maruyama T, Kaji Y, Harada M, et al. Detection of cardiovascular risk factors by indices of obesity obtained from anthropometry and dual-energy X-ray absorptiometry in Japanese individuals. Int J Obes. 2003;27:232–237.

25. Wang Z, Rowley K, Wang Z, Piers L, O’Dea K. Anthropometric indices and their relationship with diabetes, hypertension and dyslipidemia in Australian Aboriginal people and Torres Strait Islanders. Eur J Cardiovasc Prev Rehabil. 2007;14:172–178.

26. Echouffo-Tcheugui JB, Batty GD, Kivimäki M, Bengtsson B, Shaw J, et al. Importance of arterial pulse pressure as a predictor of coronary heart disease. Circulation. 2005;111:109–114.

27. Fava C, Sjögren M, Montagnana M, Danese E, Almgren P, Engström G, et al. Prediction of blood pressure changes over time and incidence of hypertension by a genetic risk score in Swedes. Hypertension. 2013;61:319–326.

28. Sullivan LM, Massaro JM, D’Agostino RB. Presentation of multivariate data for clinical use: the Framingham Study risk score functions. Stat Med. 2004;23:1631–1660.