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# Health risk factors and the incidence of hypertension: 4-year prospective findings from a national cohort of 60 569 Thai Open University students

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## ABSTRACT

**Objective:** This study evaluates the impact of a number of demographic, biological, behavioural and lifestyle health risk factors on the incidence of hypertension in Thailand over a 4-year period.

**Design:** A 4-year prospective study of health risk factors and their effects on the incidence of hypertension in a national Thai Cohort Study from 2005 to 2009.

**Setting:** As Thailand is transitioning from a developing to a middle-income developed country, chronic diseases (particularly cardiovascular disease) have emerged as major health issues. Hypertension is a major risk factor for heart attack and stroke and cross-sectional studies have indicated that the prevalence is increasing.

**Study participants:** A total of 57 558 Sukhothai Thammathirat Open University students who participated in both the 2005 and 2009 questionnaire surveys and who were normotensive in 2005 were included in the analysis.

**Measures:** Adjusted relative risks associating each risk factor and incidence of hypertension by sex, after controlling for confounders such as age, socioeconomic status, body mass index (BMI) and underlying diseases.

**Results:** The overall 4-year incidence of hypertension was 3.5%, with the rate in men being remarkably higher than that in women (5.2% vs 2.1%). In both sexes, hypertension was associated with age, higher BMI and comorbidities but not with income and education. In men, hypertension was associated with physical inactivity, smoking, alcohol and fast food intake. In women, hypertension was related to having a partner.

**Conclusions:** In both men and women, hypertension was strongly associated with age, obesity and comorbidities while it had no association with socioeconomic factors. The cohort patterns of socioeconomy and hypertension reflect that the health risk transition in Thais is likely to be at the middle stage. Diet and lifestyle factors associate with incidence of hypertension in Thais and may be amenable targets for hypertension control programmes.

## ARTICLE SUMMARY

### Article focus

- In a large Thai Cohort Study, we measured the effect of exposure to health risk factors recorded in 2005 on the incidence rate of hypertension over the following 4 years. This is part of a study of the health risk transition underway in Thailand. We investigated sociodemographic factors, comorbidity, body size, physical activity and health behaviour. The cohort members are Open University students, live nationwide, are well educated and of modest means, representing the next generation of adult Thais.

### Key messages

- Overall, the incidence of self-reported hypertension in Thai adults was 3.5%, with the rate for men being much higher than for women (5.2% vs 2.1%). In both sexes, hypertension incidence was associated with age, higher body mass index, kidney disease, diabetes and high lipids, but not with socioeconomic status.
- Marriage or partnering increased the risk of hypertension in women but not in men. Planned physical activity, averaged across the 4-year follow-up, protected males: ≥15 sessions/week was associated with lower incidence of hypertension. However, this was not observed in women.
- In men, current smokers had a higher risk of developing hypertension than non-smokers while in women smoking (which was rare) had no apparent hypertension effect. Among men, regular drinking increased the risk of incident hypertension.

### Strengths and limitations of this study

- In Thailand, this cohort constitutes the largest longitudinal study of health risk factors and hypertension development. As a consequence, many independent risk factors for hypertension in Thais can be identified. Our cohort represents Thais well in geography and socioeconomy, so the results reflect trends of the health risk transition in the population.
- Our study relies on self-report. There may be recall and reporting errors. Some risk factors may take more than 4 years to produce hypertension and will manifest as the cohort ages.

## INTRODUCTION

Hypertension is a global public health challenge due to its high prevalence and the concomitant increase in risk of stroke and cardiovascular diseases.[1] In 2007, according to WHO, cardiovascular diseases caused 33.7% of all deaths in the world, while other chronic diseases were responsible for 26.5%.[2] Globally, it has been estimated that premature deaths resulting from hypertension annually are approximately 7.1 million, which account for 64 million disability-adjusted life years (DALYs).[3] Hypertension ranks third, after underweight and unsafe sex, in the list of six major risk factors contributing to the global disease burden.[3]

In Thailand, hypertension is the third major risk factor associated with national disease burden and causing 600 000 DALY losses per year.[4] The prevalence of hypertension has been estimated from a number of cross-sectional studies among adults and has been increasing over the past decades from 20% in 1985 to 22% in 2004.[4–6] The recent Thai National Health Examination Survey in 2009 reported that the prevalence of hypertension in adults was 21.5%.[4] The emergence of hypertension has been the result of rapid socioeconomic development, which has resulted in one-third of Thais migrating to urban areas.[7] Urbanisation has been associated with increased obesity as people become less physically active and adopt sedentary lifestyles such as spending more time watching television and sitting and using computers.[7 8] These factors, in association with Thailand's ageing population,[9] underpin the importance of controlling hypertension in the Thai community.

There is limited longitudinal research on health risk factors and hypertension incidence in Thailand.[5] The purpose of this study was to address that knowledge gap. We prospectively examined the influence of an array of demographic, biological, health risk and lifestyle factors on the incidence of hypertension during 4 years of follow-up in the Thai Cohort Study (TCS). This is part of an overarching research programme investigating Thailand's health risk transition from high maternal child and infectious disease mortality to increased longevity and emerging chronic disease. The large national cohort of Thai adults reported on here has been followed since 2005 for risk factor trends and associated disease outcomes, including hypertension.

## METHODS

### Study population

The first TCS evaluation was conducted in 2005 by sending 20-page health risk questionnaires to the 200 000 distance-learning students enrolled at Sukhothai Thammathirat Open University (STOU) and 87 134 (44%) completed them and signed the consent forms. The cohort has been shown to be socioeconomically and geographically well representative of the Thai population.[10] However, they resided more in urban areas (51.8% vs 31.1%) and, on average, were younger and better educated than most Thai adults. Details of the baseline TCS methodology have been published.[10] This questionnaire focused on sociodemography, habitation, work, health services, injury, sedentary habits, physical activity, transport, underlying diseases, family history, personal behaviours, body mass index (BMI), and consumption of foods, vegetables and fruit. A 4-year follow-up was carried out in 2009. Overall, 71% of the cohort responded generating longitudinal data on 60 569 participants.

### Incident hypertension

Incident hypertension was defined as being normotensive in 2005 and self-reported doctor diagnosed hypertensive in 2009. Hypertension incidence was the dependent variable for analyses and the person-time denominator included all individuals at risk—those 57 558 participants with longitudinal data who were negative for hypertension in 2005, the beginning of the 4-year study period.

### Risk factors

Hypertension was defined as described above; the underlying diseases diagnosed by a doctor were also reported, including diabetes mellitus, kidney diseases and high blood lipids, all of which were investigated as potential risk factors of hypertension.

Participants were grouped into three age categories: younger (≤30 years), middle (31–40 years) and older (>40 years). Urbanisation status was based on rural (R) or urban (U) residence, first when aged 10–12 years old and again in 2005, producing four groups: lifelong ruralites (RR), urbanisers (RU), de-urbanisers (UR) and urbanites (UU). Personal monthly income was divided into four categories: ≤7000, 7001–10 000,10 001–20 000 and >20 000 baht. In 2005, one US dollar was equivalent to 42 baht, so most of the participants had quite low incomes. Household assets were classified into three categories: low (≤30 000 baht), medium (30 001–60 000 baht) and high (>60 000 baht).

Sedentariness was assessed by screen time (hours/day spent before the TV or computer) and (separately) sitting time (hours per day spent sitting for any purpose). Incidental exercise was measured by the frequency of housework or gardening, categorised as follows: ≤3 times/month; 1–2 times/week; 3–4 times/week; most days. We measured planned physical activity at the beginning and end of the 4-year follow-up period. On both occasions, cohort members reported the number of sessions per week of strenuous and moderate exercise for at least 20 min, and of walking for at least 10 min. We derived an 'overall measure' of planned physical activity calculated separately at both the baseline and the 4-year mark. The measure was weighted as follows: (2×strenuous+1×moderate+1×walking) sessions per week. This weighting system is based on the recommendation of the International

Physical Activity Questionnaire and the Active Australia Survey as used in other analyses of the cohort data.[11 12] Finally, for each individual, the 'overall measures' of weekly exercise for 2005 and 2009 were added and then averaged by dividing by 2, creating a longitudinal measure of planned physical activity (LPPA).

Smoking status was classified as a never smoker, ex-smoker or current-smoker. Alcohol exposure was classified by four categories: never drinker, ex-drinker, occasional drinker or current drinker. BMI was calculated from self-reported height in metres and weight in kilograms as weight/height$^2$. It was divided into four categories as follows according to Asian criteria[8 13–16]: underweight (BMI <18.5), normal (18.5 to <23), overweight (23 to <25) and obese (≥25). Foods that could potentially influence blood pressure (deep fried, instant, roast or smoked soybean products and soft drinks) were assessed for consumption frequency based on a five-point Likert scale ranging from less than once a month to once or more a day. Western-style fast food exposure was noted on a three-point scale from less than once to more than three times a month. Fruit and vegetable consumption was recorded as standard serves eaten per day.

### Statistical analyses

All analyses were performed using SPSS software. The incidence of hypertension and its 95% CI were calculated for each value of each categorical variable in both male and female participants and the influence on incidence by each variable was evaluated by $\chi^2$ test. For statistical inference, all p values were two tailed and significance was set at 5%.

Relative risks (RRs) in a large study of an uncommon disease (incidence less than 10%) can be accurately estimated as odds ratios (ORs).[17] Accordingly, for each risk variable, the RR and 95% CI were estimated using logistic regression to calculate the bivariate OR for hypertension. Adjusted RRs (ARRs) were estimated by calculating multivariate logistic regression ORs. ARRs were controlled for confounding by age, marital status, socioeconomic status (SES), BMI, underlying diseases and personal behaviours (cigarette smoking and alcohol drinking). A variable was included in a multivariate model if bivariate analysis had indicated a statistically significant association with incidence of hypertension. Some variables were included because earlier analyses reported elsewhere had shown a significant or substantial association with hypertension.

## RESULTS

### Baseline characteristics

The baseline characteristics of study participants self-reporting as normotensive in 2005 are shown in table 1. The highest proportion of men resided in the North-eastern and Central regions while there were more women in the Central and Bangkok areas. More than half of the male and female participants lived in urban areas. Men had a higher monthly income than women, whereas women had a higher educational attainment than men. The distribution of household assets for men and women was similar and over half of them were in medium and high categories. The study population had a similar sociodemography, income and location of residence to the general Thai population.[9]

### Incidence and risks of hypertension

Overall, the incidence of self-reported doctor diagnosed hypertension in Thai adults was 3.5% and the rate in men was more than twice the corresponding rate in women (5.2% vs 2.1%; table 2). In men and women, the incidence of hypertension increased with increasing age. Marriage or having a partner increased the risk of hypertension in women. However, this was not noticed in men. Educational attainment and personal income had no influence on the risk of hypertension in both sexes. In men and women, the risk of hypertension increased with an increased BMI. The risk of hypertension increased in both men and women who had diabetes mellitus, high blood lipids and kidney disease.

Planned physical activity, averaged across the 4-year follow-up, was protective for men. In men, higher LPPA (≥15 sessions/week) was associated with lower incidence of hypertension; however, this association was not observed in women. In men, current smokers had a higher risk of developing hypertension than non-smokers while in women, smoking (which was rare) had no apparent hypertension effect. Among men, regular drinking increased the risk of incident hypertension; patterns of RRs were similar for women but, reflecting the low frequency of female drinking, did not reach statistical significance. In men, the risk of hypertension had a direct association with the frequency of instant food consumption, but there was no such association detected in women.

Over the 4-year period, a variety of factors that could have been risks for hypertension over a longer period were found not to be in this setting (data not shown). Thus, in men and women, factors that had no statistically significant influence on the longitudinal 4-year risk of hypertension incidence were urbanisation status, sedentary lifestyle (non-participation in housework or gardening, high levels of television and computer watching, sleeping and sitting time) and food consumption habits that included deep-fried food and soft drinks, Western fast food, roasted or smoked foods, fruit, vegetables and soybean products.

## DISCUSSION

This large prospective cohort of adults living all over Thailand has been the first studied nationally for a wide array of risk factors for incident hypertension. Overall, the 4-year incidence of hypertension from 2005 to 2009 was 3.5%, notably higher in men (5.2%) than women (2.1%). These incidence rates are drawn from a cohort of adults on average younger than the Thai population,

**Table 1** Characteristics of 57 558 normotensive participants at the 2005 Thai Cohort Study baseline

| Factor | Male N | Male Per cent | Female N | Female Per cent | Difference p Value* |
|---|---|---|---|---|---|
| Demographic data | | | | | |
| Participants | 25 320 | 44.0 | 32 238 | 56.0 | <0.0001 |
| Age (years) mean | 32.9 | | 30.0 | | <0.0001† |
| (SD) | (8.5) | | (7.6) | | |
| Age group (years) | | | | | <0.0001 |
| ≤30 | 11 293 | 44.6 | 19 229 | 59.6 | |
| 31–40 | 9177 | 36.2 | 9638 | 29.9 | |
| >40 | 4850 | 19.2 | 3371 | 10.5 | |
| Married/partnered | | | | | <0.0001 |
| No | 11 060 | 44.8 | 18 851 | 60.1 | |
| Yes | 13 607 | 55.2 | 12 513 | 39.9 | |
| Regions | | | | | <0.0001 |
| Bangkok | 3488 | 13.9 | 6057 | 18.9 | |
| Central | 5712 | 22.7 | 8267 | 25.8 | |
| North | 5180 | 20.6 | 5818 | 18.1 | |
| North-east | 6142 | 24.4 | 5760 | 18.0 | |
| East | 1515 | 6.0 | 1922 | 6.0 | |
| South | 3103 | 12.3 | 4254 | 13.3 | |
| Urbanisation status‡ | | | | | <0.0001 |
| Rural–rural (RR) | 11 512 | 46.1 | 13 895 | 43.6 | |
| Rural–urban (RU) | 7891 | 31.6 | 9546 | 29.9 | |
| Urban–rural (UR) | 1078 | 4.3 | 1344 | 4.2 | |
| Urban–urban (UU) | 4495 | 18.0 | 7114 | 22.3 | |
| Socioeconomic status | | | | | |
| Education level | | | | | <0.0001 |
| High school | 13 366 | 52.9 | 13 135 | 40.8 | |
| Diploma | 5749 | 22.8 | 9791 | 30.4 | |
| University | 6153 | 24.4 | 9231 | 28.7 | |
| Personal monthly income (baht)§ | | | | | <0.0001 |
| ≤7000 | 8025 | 32.3 | 13 890 | 44.1 | |
| 7001–10 000 | 5790 | 23.3 | 7578 | 24.0 | |
| 10 001–20 000 | 7549 | 30.4 | 7194 | 22.8 | |
| >20 000 | 3452 | 13.9 | 2851 | 9.0 | |
| Household assets¶ (baht) § | | | | | <0.001 |
| Low | 9852 | 39.1 | 12 434 | 38.7 | |
| Medium | 8065 | 32.0 | 9863 | 30.7 | |
| High | 7298 | 28.9 | 9804 | 30.5 | |

*$\chi^2$ Test.
†Unpaired t test.
‡Location of residence (rural, R or urban, U) at age 10–12 years and again in 2005.
§At the time of the survey in 2009, US$1=31 Thai baht.
¶Replacement value in Thai baht: low ≤30 000, medium 30 001–60 000 and high >60 000.

so they are lower than the corresponding rates of the adult population. However, our focus was on risk-factor associations and we noted that in both sexes, age, obesity and comorbidity with diabetes mellitus, high blood lipids and kidney disease were strongly linked to hypertension incidence. In men, instant food consumption, smoking and drinking alcohol had a moderate adverse effect on hypertension risk while planned physical activity averaging 15 or more sessions per week over the 4-year period was substantially protective, reducing risk by 22%. In women, having a partner was associated with increased incidence of hypertension.

The age effect on hypertension incidence noted by us is consistent with the findings of many other population studies of hypertension including, for example, a longitudinal study in China[18] and cross-sectional studies in Korea,[19] Taiwan[20] and the USA.[21] The noticeably greater incidence of hypertension in men than in women that we found in Thailand has also been reported from many parts of the world including neighbouring Malaysia[22] and distant USA[23] as well as in a recent global review.[24]

In men and women of the Thai cohort, a progressively higher BMI was positively and significantly associated with an increased risk of incident hypertension over the 4 years. This finding was similar to that reported for other prospective cohorts in the USA[25 26] and Finland.[27] Furthermore, after 7 years of follow-up in a US study,[28]

**Table 2** Hypertension incidence and association with risk factors in male and female participants

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | HT (n) | Inci%* (95% CI) | ARR† (95% CI) | HT (n) | Inci%* (95% CI) | ARR† (95% CI) |
| Participants | 1306 | 5.2 (4.9 to 5.4) | | 690 | 2.1 (2.0 to 2.3) | |
| *Demography* | | | | | | |
| Age group (years) | | | | | | |
| ≤30 | 279 | 2.5 (2.2 to 2.8) | 1 | 215 | 1.1 (0.97 to 1.3) | 1 |
| 31–40 | 484 | 5.3 (4.8 to 5.7) | 1.66 (1.39 to 1.98) | 245 | 2.5 (2.23 to 2.9) | 1.93 (1.56 to 2.39) |
| >40 | 543 | 11.2 (10.3 to 12.1) | 3.13 (2.57 to 3.81) | 230 | 6.8 (6.0 to 7.7) | 4.2 (3.26 to 5.42) |
| P-trend | | <0.0001 | <0.0001 | | <0.0001 | <0.0001 |
| Marital status (married/partnered) | | | | | | |
| No | 368 | 3.3 (3.0 to 3.7) | 1 | 303 | 1.6 (1.43 to 1.8) | 1 |
| Yes | 896 | 6.6 (6.17 to 7.0) | 0.97 (0.83 to 1.12) | 368 | 2.9 (2.65 to 3.2) | 1.22 (1.03 to 1.45) |
| *Socioeconomic status* | | | | | | |
| Education level | | | | | | |
| High school | 697 | 5.2 (4.8 to 5.6) | 1 | 303 | 2.3 (2.05 to 2.57) | 1 |
| Diploma | 276 | 4.8 (4.25 to 5.4) | 1.0 (0.86 to 1.17) | 180 | 1.8 (1.57 to 2.1) | 0.81 (0.66 to 0.99) |
| University | 331 | 5.4 (4.8 to 5.9) | 0.93 (0.8 to 1.1) | 204 | 2.2 (1.9 to 2.51) | 0.87 (0.71 to 1.07) |
| P-trend | | 0.83 | 0.61 | | 0.463 | 0.1 |
| Personal monthly income (baht)‡ | | | | | | |
| ≤7000 | 268 | 3.3 (2.95 to 3.7) | 1 | 217 | 1.6 (1.36 to 1.8) | 1 |
| 7001–10 000 | 229 | 4.0 (3.45 to 4.5) | 1.0 (0.81 to 1.2) | 142 | 1.9 (1.57 to 2.2) | 1.1 (0.87 to 1.37) |
| 10 001–20 000 | 497 | 6.6 (6.0 to 7.14) | 1.1 (0.91 to 1.31) | 196 | 2.7 (2.35 to 3.1) | 0.97 (0.77 to 1.23) |
| >20 000 | 289 | 8.4 (7.46 to 9.3) | 1.0 (0.8 to 1.25) | 122 | 4.3 (3.54 to 5.0) | 1.04 (0.78 to 1.39) |
| P-trend | | <0.0001 | 0.527 | | <0.0001 | 0.783 |
| BMI classification§ | | | | | | |
| Underweight (BMI <18.5) | 359 | 2.9 (2.62 to 3.2) | 0.46 (0.27 to 0.78) | 60 | 0.85 (0.63 to 1.15) | 0.9 (0.67 to 1.21) |
| Normal (18.5≤BMI<23) | 16 | 1.1 (0.56 to 1.6) | 1 | 258 | 1.4 (1.2 to 1.5) | 1 |
| Overweight (23≤BMI<25) | 333 | 5.9 (5.3 to 6.54) | 1.66 (1.41 to 1.95) | 129 | 3.9 (3.3 to 4.62) | 2.32 (1.8 to 2.91) |
| Obese (BMI ≥25) | 575 | 10.4 (9.6 to 11.2) | 2.82 (2.43 to 3.27) | 231 | 7.4 (6.4 to 8.27) | 4.14 (3.4 to 5.05) |
| P-trend | | <0.0001 | <0.0001 | | <0.0001 | <0.0001 |
| *Physical activities* | | | | | | |
| Weighted total sessions exercise-related physical activity (average between 2005 and 2009) | | | | | | |
| 0–7 ses/week¶ | 198 | 6.3 (5.5 to 7.1) | 1 | 162 | 2.2 (1.8 to 2.6) | 1 |
| 8–14 ses/week | 589 | 5.2 (4.8 to 5.6) | 0.9 (0.76 to 1.07) | 352 | 2.1 (1.9 to 2.3) | 1.0 (0.82 to 1.23) |
| ≥15 ses/week | 380 | 4.4 (4.0 to 5.0) | 0.78 (0.65 to 0.95) | 119 | 2.2 (1.8 to 2.6) | 1.0 (0.77 to 1.3) |
| P-trend | | <0.0001 | <0.029 | | 0.905 | 1.0 |
| *Underlying diseases* | | | | | | |
| Diabetes mellitus | | | | | | |
| No | 1251 | 5.0 (4.7 to 5.27) | 1 | 674 | 2.1 (1.9 to 2.26) | 1 |
| Yes | 55 | 18.3 (13.9 to 22.7) | 1.81 (1.29 to 2.52) | 16 | 10.7 (5.7 to 15.8) | 2.54 (1.41 to 4.56) |
| High lipids | | | | | | |
| No | 983 | 4.4 (4.13 to 4.67) | 1 | 576 | 1.9 (1.76 to 2.1) | 1 |
| Yes | 323 | 10.8 (9.7 to 11.9) | 1.4 (1.21 to 1.63) | 114 | 5.4 (4.47 to 6.4) | 1.38 (1.09 to 1.75) |
| Kidney diseases | | | | | | |
| No | 1248 | 5.1 (4.8 to 5.33) | 1 | 659 | 2.1 (1.9 to 2.26) | 1 |
| Yes | 58 | 9.6 (7.2 to 11.9) | 1.62 (1.19 to 2.2) | 31 | 3.9 (2.52 to 5.2) | 1.77 (1.19 to 2.63) |
| *Personal behaviours* | | | | | | |
| Smoking status | | | | | | |
| Never smoker | 506 | 4.1 (3.7 to 4.4) | 1 | 617 | 2.1 (1.9 to 2.23) | 1 |
| Ex-smoker | 496 | 6.6 (6.0 to 7.13) | 1.15 (1.0 to 1.32) | 37 | 3.2 (2.2 to 4.22) | 1.28 (0.88 to 1.87) |
| Current smoker** | 276 | 5.8 (5.16 to 6.5) | 1.22 (1.04 to 1.44) | 8 | 3.1 (0.97 to 5.2) | 1.54 (0.74 to 3.2) |
| P-trend | | <0.0001 | <0.032 | | <0.008 | 0.23 |
| Drinking status | | | | | | |
| Never drinker | 105 | 3.9 (3.2 to 4.7) | 1 | 268 | 2.1 (1.8 to 2.32) | 1 |
| Ex-drinker | 155 | 5.7 (4.85 to 6.6) | 0.98 (0.74 to 1.3) | 50 | 2.2 (1.6 to 2.85) | 1.14 (0.82 to 1.59) |
| Occasional drinker†† | 821 | 4.8 (4.45 to 5.1) | 1.0 (0.8 to 1.25) | 352 | 2.1 (1.9 to 2.36) | 1.14 (0.96 to 1.36) |

Continued

**Table 2** Continued

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | HT (n) | Inci%* (95% CI) | ARR† (95% CI) | HT (n) | Inci%* (95% CI) | ARR† (95% CI) |
| Regular drinker‡‡ | 212 | 8.6 (7.5 to 9.7) | 1.61 (1.23 to 2.11) | 9 | 4.7 (1.66 to 7.7) | 1.83 (0.86 to 3.9) |
| P-trend | | <0.0001 | <0.0001 | | 0.471 | 0.254 |
| *Food consumption habit* | | | | | | |
| Instant food | | | | | | |
| <1 time/month | 335 | 6.3 (5.6 to 6.95) | 1 | 168 | 2.8 (2.36 to 3.2) | 1 |
| 1–3 times/month | 485 | 5.1 (4.63 to 5.5) | 1.02 (0.87 to 1.19) | 273 | 2.1 (1.84 to 2.3) | 0.95 (0.77 to 1.17) |
| 1–2 times/week | 280 | 4.4 (3.9 to 4.9) | 1.09 (0.91 to 1.30) | 153 | 1.9 (1.6 to 2.2) | 1.04 (0.81 to 1.33) |
| 3–6 times/week | 165 | 5.0 (4.3 to 5.75) | 1.36 (1.1 to 1.69) | 73 | 1.8 (1.4 to 2.22) | 1.14 (0.84 to 1.55) |
| ≥1 times/day | 32 | 5.5 (3.6 to 7.33) | 1.67 (1.11 to 2.52) | 18 | 2.3 (1.3 to 3.35) | 1.48 (0.86 to 2.53) |
| P-trend | | <0.002 | <0.008 | | <0.002 | 0.403 |

*Incidence of hypertension.
†ARRs were calculated from multivariate logistic regression models of hypertension adjusted for age, marital status, education, income, BMI category, underlying diseases, personal behaviours.
‡At the time of the survey in 2005, US$1=42 Thai baht.
§Asian standard BMI classification.
¶Sessions/week.
**Current smoker.
††Occasional drinker.
‡‡Regular drinker.
ARR, adjusted relative risk; BMI, body mass index.

weight loss was associated with a decreased risk of incident hypertension. Among a cohort of US nurses, the risk of incident hypertension increased by 5% for each kilogram of added weight,[29] and rose by 15% for each increase of 1 kg/m$^2$ of BMI in Taiwan.[18] These results suggest that the adverse effect of high BMI on risk of hypertension does not depend on ethnicity or sex and is widespread around the world.

In our cohort, we noted a higher risk of incident hypertension among those with diabetes mellitus. This finding is consistent with the longitudinal studies in the USA,[30 31] which reported that in diabetic patients the risk of incident hypertension rose by 41% and 56%, respectively. In addition, prospective cohort studies in Japan showed that diabetes[32] and impaired fasting blood glucose[33] were associated with an increased risk of hypertension incidence. Supportive cross-sectional results emerge from studies in diverse settings including Bangladesh and India,[34] Barbados[35] and the USA.[36] A causal association between diabetes and hypertension is suspected and possible mechanisms include endothelial dysfunction and vascular inflammation.[37]

We also found that high blood lipids were significantly associated with increased risk of incident hypertension. This supports the results from previous longitudinal studies in men,[38 39] women[40 41] and adults.[32 42] The risk of hypertension increased with an increase in the total cholesterol, triglyceride and low-density lipoprotein cholesterol levels and decreased with an increase in the high-density lipoprotein cholesterol level.[38 39 41] The mechanism by which dyslipidaemia provokes high blood pressure is uncertain but could reflect blood vessel dysfunction and a damaged endothelium.[43]

Among men and women in the Thai cohort, kidney disease was strongly associated with increased risk of hypertension incidence. This result is supported by cross-sectional data from the Czech Republic[44] and the USA.[45] Microalbuminuria is a biomarker for renal hypertension[45] and the risk increases with the severity of kidney impairment, revealed by the serum creatinine level.[46 47] Glomerular damage is more closely connected with hypertension than tubular or interstitial disease.[47] Chronic kidney disease facilitates high blood pressure through many mechanisms including excessive intravascular volume, increased endothelin production, activity of the renin-angiotensin system and sympathetic nervous system and decreased vasodilators, nitric oxide production and endothelial function.[48]

In men, we found that cigarette smoking was modestly associated with increased risk of developing hypertension. This is consistent with many other reports such as the longitudinal studies in Japanese[49] and American men[50] and a cross-sectional study in French men.[51] In addition, smoking Jordanian men had a significantly higher blood pressure than their non-smoking counterparts.[52] However, we also found that smoking had no influence on hypertension in women. This result for women is compatible with reports from Korea[53] and the USA.[54] In contrast, one prospective US study[55] reported an increased risk of hypertension among women. It is likely that men tend to smoke more cigarettes than women and the impact of smoking on hypertension is a dose–response pattern.[49]

Regular alcohol consumption was strongly associated with an increased risk of incident hypertension. This result is supported by findings from longitudinal studies in Japan[56 57] and cross-sectional studies in China[58] and Korea.[53] In Japanese men, alcohol consumption, particularly more than 200 g/week, was significantly associated with an increase in blood pressure[59] while alcohol

restriction was noticeably related to a decreased blood pressure.[60] Among women in our Thai cohort, alcohol consumption had no influence on hypertension; this result was supported by longitudinal data from Japan[56] and cross-sectional data from Korea.[53] In American women, the quantity of alcohol consumption per week had no effect on systolic blood pressure.[61] Men usually consume more alcohol than women and the hypertension risk is linear with a dose–response.[57 62] Our results suggest that regular alcohol consumption, especially in men, is a significant risk factor for developing hypertension.

Marital status in men had no influence on hypertension, which supports the results from more economically developed countries, the USA and Korea.[53 54] However, in middle-income countries, the results diverged: married men, when compared with their unmarried counterparts, had a higher risk of hypertension in Barbados[35] and a lower risk in Poland.[63] Married individuals had higher emotional and social support and lower stress[63] and the probability of being a current smoker.[64] We found that incident hypertension was relatively more frequent among married women, unlike the no-sex-link pattern in developed countries such as the USA and Korea.[53 54] The influence of marrital status on hypertension varies from one country to another, partly due to the difference of socioeconomy and social structure. For our Thai cohort, the pattern in men was similar to that in developed countries, whereas in women it was not.

Participant educational attainment did not protect against hypertension in either sex. This is similar to the cross-sectional results for adults in developed countries such as Korea[53] and the USA.[36 65] However, other studies in various settings and with diverse designs reported that educational attainment protects against hypertension in adults; these included a prospective cohort in middle-income Thailand,[5] a cross-sectional study in middle-income Malaysia[22] and a cross-sectional study in high-income USA.[66] Opposite findings have been reported in low-income settings in both Bangladesh and India[34] where education was a risk factor for hypertension. Taken collectively, these data suggest that income modifies the protective education-hypertension effect, inverting it when income is low and boosting it when income is high. Our middle-income cohort could be in the middle stage of this education effect as it is transiting from the low-income pattern.

We found no association between personal monthly income and risk of hypertension in either sex. This was similar to previous studies in middle-income countries including a longitudinal study in Thailand[5] and a cross-sectional study in Malaysia[67] and in cross-sectional studies in high-income countries such as Korea[53] and the USA.[21 36] However, income had an inverse association with risk of hypertension in another study in high-income developed USA[65] while it had a direct positive association in a low-income developing country such as Ghana.[68] The health transition in Thailand is likely to be in the middle stage, according to the concept of a tipping point for the relationship between SES, body size and hypertension risk factors. High income, large body size and high blood pressure are seen in developing countries while in developed countries, high income is a protective factor.[69–71] Indeed, the Thai cohort has already been shown to be at a transitional point for metabolic states because women had an inverse relationship between income and BMI while men had a positive (traditional) relationship.[14] However, now all Thais benefit from universal health insurance, so access to healthcare is not dependent on their income making disease associations more attenuated than before.[72]

In our cohort, the reduction in risk of hypertension incidence in men but not in women by LPPA was comparable with a prospective study in middle-aged American whites.[73] In another prospective study in middle-aged Finns, the hypertension protective effect of vigorous physical activity or total energy expenditure from leisure-time physical activity was observed in men but not in women.[74] Such physical activity among women may be less intense than among men, thus having no effect on the risk of hypertension.[74] A large Finnish study[27] demonstrated that the incidence of hypertension was inversely associated with the level of physical activity in a dose–response manner in both sexes. In our cohort study, risk of obesity had an inverse association with quantified planned exercise in both sexes, but the effect was significantly stronger in men than in women.[12] As Thailand progresses economically, more people migrate to urban areas and decrease their physical activity.[7] Therefore, in the future, Thai people may encounter a higher risk of hypertension due to lower physical activity.

Instant food—mostly combinations of carbohydrate, fat and salt—is associated with an increased risk of incident hypertension in men but not in women. Other foods, fruit and vegetables had no impact on hypertension. This may be the result of men comsuming more instant foods, such as instant noodles, than women. For example, a study in Korea showed that the daily instant food consumption in men and women averages 23.7 and 11.1 g, respectively.[75] Other studies have shown that carbohydrate,[76 77] fruit and vegetables[78 79] consumption had no influence on hypertension. Most students consume instant noodles, which lead to a higher intake of energy, fat, sodium, thiamine and riboflavin but a lower intake of protein, calcium and phosphorus.[75] Koreans favouring instant noodles have a salt intake more than three times higher than the daily recommendation (6.4 vs 2 g).[75] The daily salt intake of Thai people has been reported to average 10.8 g, which is much higher than that recommended (http://www.worldactiononsalt.com/worldaction/asia/75286.pdf). High salt consumption was associated with increased risk of developing hypertension in a longitudinal study in Taiwan[80] and in cross-sectional studies in China[81 82] while other reports revealed that salt restriction reduced blood pressure.[83 84] Owing to the overwhelming capacity of the

kidney to excrete excessive salt consumption, high plasma sodium leads to excessive intravascular volume and high blood pressure.[85] It seems reasonable to conclude that high salt intake from instant noodle consumption is likely to be causally associated with an increased risk of hypertension in Thailand.

In Thailand, this cohort constitutes the largest study to examine the longitudinal effect of most health risk factors on hypertension development. Indeed, the study size, along with its national representation, is an important factor to consider when exploring study validity and utility. The influence of risk factors on hypertension incidence is clearly demonstrated since this is a large longitudinal cohort covering a 4-year period. As a consequence, independent risk factors for hypertension in Thais can be identified. With the high initial non-response rate, participants drawn from only one university distance-learning students enrolled at STOU may not be representative of the Thai people or the next generation of Thais. However, our nationwide cohort represents the STOU students well, as well as the Thai population in geography and socioeconomy,[9] so the results to some extent reflect the trend of health risk transition in the Thai population. Indeed, the STOU students, with better education attainment combined with their representative incomes and geographical location, are likely to represent the next generation of Thais. It would be reasonable to conclude that our 4-year follow-up results may indicate future hypertension trends for Thai people.

However, our study has limitations since it relied on self-report. There may be recall and reporting errors. But a study of the validity of self-reported weight and height in our cohort found that the accuracy was quite acceptable.[86] In addition, we have conducted a validation study of self-reported hypertension (Prasutr Thawornchaisit, 2013, under review) in a random age-sex matched subsample of the cohort reporting hypertension (n=240) or no hypertension (n=240). We found that the sensitivity was high (82%) and that the negative reports were usually accurate (86%). In another report, we investigated the impact of the non-responses to the 2009 follow-up and found small effects with under-representation of young urban men; this missing group would have a minor influence on our results and would not be expected to have a high rate of incident hypertension.[87] The findings from our study are likely to be robust and represent well the future trends of health risk transition in middle-income Thailand and similar ASEAN countries.

In conclusion, older age, obesity and underlying morbidity due to diabetes, high blood lipids and kidney disease were strongly associated with increased risk of incident hypertension in both sexes while in men, physical inactivity, instant food consumption, smoking and drinking alcohol had a moderate association. A sedentary lifestyle and the consumption of fruit and vegetables had no detected influence on hypertension. The Thai health risk transition is likely to be in the middle stage since education attainment and income still have no net effect to protect against hypertension. Prevention should focus on obesity, high blood lipids and high salt consumption and people should be encouraged to increase physical exercise and consume low fat foods and less instant foods. A reduction of salt consumption should be a national policy by limiting the concentration of salt in ready-to-eat and industrial foods. Smoking and drinking cessation should be promoted for men. Thailand should also consciously aim to take advantage of its culturally determined low rate of drinking and smoking among women and ensure that there is no attempt to undermine this situation and develop the market for the female half of the population.

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**Contributors** PT devised the hypertension study, analysed the data and wrote the paper. FDL and CMR assisted with the planning of the study, analysis and interpretation. ACS and SS conceived and developed the cohort, and helped plan, analyse and interpret this study. All authors approved the final manuscript.

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