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# Defining risk thresholds: Appropriate body mass index cut-off for hypertension in Thai Cohort Study

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## Abstract

Body mass index (BMI) is used to predict the risk of hypertension in some Western countries. But to date the appropriate BMI cut-off for hypertension among Thais remains unresolved. This study aims to determine the proper BMI cut-off for risk of hypertension in Thailand.

Health-risk factors and their effects on incidence of hypertension were evaluated prospectively in the national Thai Cohort Study from 2005 to 2013. All derived from 40548 initially normotensive Sukhothai Thammathirat Open University students returning mail-based questionnaire surveys in both 2005 and 2013. Adjusted relative risks of association between baseline BMI and 8-year incidence of hypertension were calculated after controlling for a wide array of confounding factors. A smooth model with a linear fit of associations between BMI and hypertension risk was compared to a non-linear model using cubic splines.

In Thailand, the 8-year incidence of hypertension was 5.1% (men 7.1%, women 3.6%). Hypertension was strongly associated with ageing and high BMI. Non-linear modelling showed the best fit with a significant upwards inflection pointing to the risk threshold occurred in the third BMI category of 20.75 (aRR = 1.89, 95% CI 1.54-2.32) compared to a reference BMI of 20.00 $kg/m^2$.

The health risk transition Thailand has led to a rising prevalence of hypertension which is an important risk factor for many chronic diseases. A BMI cut-off point of 21 $kg/m^2$, two points lower than the current 23 $kg/m^2$, would be appropriate for defining the threshold of hypertension risk in Thai adults. Lowering BMI cut-off for risk of hypertension will encourage people to have more awareness of their health. Our results support population level interventions design to increase exercise and decrease overweight and obesity in Thailand.

**Keywords:** hypertension, body mass index, cut-off point for hypertension, Thailand

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## 1. Introduction

Rapid economic growth in recent decades moved Thailand from a low- to a middle-income country with a concomitant steady increase in urbanization. As a result, the proportion living in cities increased from 20.9% in 1970 to 34.1% in 2011 and it is estimated that over one million Thais (1.6% of population) will be urbanized each year [1]. Urban residence tends to accompany a sedentary life-style, junk food consumption [2], higher meat and lower rice consumption and other unhealthy behaviours, especially excessive drinking and smoking [3]. There is also a higher risk of obesity [2, 4, 5]. The socio-economic and environmental transformations are changing disease patterns of Thais to resemble those in developed countries, especially emerging non-communicable diseases including hypertension [6]. Many studies concluded that overweight and obesity are major risk factors of hypertension [7-12]. Increasing BMI is associated with increased morbidity and mortality due to increasing risk of obesity related problems such as cardiovascular disease, stroke and diabetes mellitus [13, 14]. WHO

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recommends that bodyweight classifications be based on body-mass index calculated as weight in kilograms divided by height in meters squared ($kg/m^2$) and categorized by standard cut-offs [14]. In addition, WHO approved different BMI cut-offs for "normal", "overweight" and "obese" for Asian populations as follows: less than 18.5 $kg/m^2$ underweight; ($18.5 \leq$ BMI $<$ 23.0) $kg/m^2$ normal; ($23 \leq$ BMI $< 25$) $kg/m^2$ overweight at risk; and 25 $kg/m^2$ obeseI [15]. Even these criteria may not be strict enough and we know that the lower levels of BMI still increase cardiovascular and metabolic disorder rates in some Asian populations [16-18]. The BMI cut-off values at 23 and 25 $kg/m^2$ respectively for overweight and obesity, recommended by WHO for Asian populations, is still too high for Singaporeans. They should be lower by 2–3 $kg/m^2$ (18, 19). Many studies showed that the association of BMI and percentage of body fat among different ethnic groups was not similar [20-23] so BMI cut-off point based on body fat should be defined according to ethnicity. At the same percentage of body fat, Singaporean should have a BMI lower than Caucasian people [19, 24]. Our Thai Cohort Study (TCS) is focused on the transition in health risks due to modernization. Here we study the impacts on population health, investigating demography, socio-economy, physical activities, personal behaviour and other health risks associated with hypertension during 8 years of prospective follow-up. The normal Asian body mass index cut-offs ($18.5 \leq$ BMI $< 23$) may be too high for Thais since participants at normal body mass index still have an annual incidence of hypertension of nearly 3% [9]. Therefore, in Thailand BMI cut-offs for hypertension could need national adjustment so we performed an incidence study to determine the risk.

## 2. Methods

### 2.1. *Study Population and Data*

The Thai Cohort Study (TCS) began in 2005 with 87151 distance learning students enrolled at Sukhothai Thammathirat Open University (STOU) then representing 44% of the enrolled student population [6]. The STOU student body and the TCS members were similar to the Thai people for geography and socio-economic status [25] but their age distributions are different. The student body and cohort members were younger with 56.2% and 51.5% respectively in the 21-30 year age range compared to 23.9% in the general Thai population and fewer were older than 50 years (1.2% and 2% respectively) compared with 24.7% of the Thai population. Also, in comparison with the general population, the STOU student body and TCS members had a higher education. TCS baseline data were generated from a 20-page mail-out questionnaire which included questions on demography, socio-economic status (SES), personal health and diseases (diabetes mellitus, high blood lipids, high blood pressure, stroke, chronic kidney disease, various cancers, goitre, epilepsy, asthma, arthritis, chronic bronchitis and depression). As well there are questions on hearing, vision, dental impairment, use of health services, transport, injury, social networks, personal well-being, health-related behaviour and family background. Baseline data have been published [6, 25]. The number of cohort members participating at 4-year follow up was 60569 (70%) in 2009 and there were 42785 responders (49%) in 2013 at 8-year follow up.

### 2.2. *Incident hypertension*

Incident hypertension was defined as self-report of doctor diagnosed hypertension in 2013 after being normotensive in 2005. Hypertension incidence was the binary dependent variable for analyses and the person-time denominator included all individuals at risk—those 40548 (94.8%) of the 42785 participants with 8-year longitudinal data (2005 to 2013) who were negative for hypertension at the start (2005).

### 2.3. *Independent variables*

The independent variables that were available for analysis included age, sex, marital status, socio-economic status (SES - income, household assets, and education), urbanization, body mass index (BMI), and underlying diseases (diabetes mellitus, high lipids and kidney disease). Other variables assessed included sedentariness (screen time, sitting time and housework or gardening), other lifestyle features (physical exercise, tobacco smoking, alcohol consumption, soy bean consumption, fruit and vegetable intake and soft drinks) and food preferences (Western, roast, smoked, instant, deep fried).

BMI calculation was based on self-report weight and height which were considered to be accurate due to the report of validation study [26]. Asian cut-offs following guidelines of the International Obesity Task Force [13]: underweight (BMI $< 18.5$), normal ($18.5 \leq$ BMI $< 23.0$), overweight ($23 \leq$ BMI $< 25.00$), or obese (BMI $\geq 25$) were used to calculate and categorize BMI. In addition, we also created 8 categories ($<$ 18.5BMI, $18.5 \geq$ BMI $< 20.75$, $20.75 \geq$ BMI $< 23$, $23 \geq$ BMI $< 25$, $25 \geq$ BMI $< 27.5$, $27.5 \geq$ BMI $< 30$,$30 \geq$ BMI $< 32.5$, and BMI $\geq 32.5$) which divided normal into two categories and more categories for obese.

Age was divided into three categories ($\leq 30$. 31-40, $> 40$). Marital status was defined as married/living with a partner or single. Urbanization status was classified in childhood (aged 12 years) and at baseline (2005) producing 4 lifelong categories: ruralites (RR), urbanizers (RU), de-urbanizers (UR) and urbanites (UU). Education level was grouped into three categories (High school, Diploma, University). Personal monthly income was divided into four categories in baht. In 2005, one US dollar was equivalent to 42 baht.

Household assets were classified into three categories (low, medium, high in baht).

Screen time and sitting time (hours/day) were proxies for sedentariness. Incidental exercise (frequency of housework or gardening), was categorised into 4 groups: ≤3 times per month; 1-2 times per week; 3-4 times per week; most days. Various forms of physical activity (at least 20 minutes of mild, moderate or strenuous exercise, 10 minutes or more walking sessions) were also included and recorded using 4-item ordinal categories.

An overall measure of planned physical activity was calculated separately at both the baseline and the 8-year mark. This was based on the cohort members reporting the number of sessions per week of strenuous and moderate exercise for at least 20 minutes, and of walking for at least 10 minutes. We weighted the measure as follows: (2×strenuous+1×moderate+1×walking) sessions per week, weighting based on the recommendation of the International Physical Activity Questionnaire and the Active Australia Survey as used in other analyses of cohort data [27, 28]. Finally, for each individual, the 'overall measures' of weekly exercise for 2005 and 2013 were added and then averaged by dividing by 2, creating a longitudinal measure of planned physical activity (LPPA).

Smoking was self-reported and grouped into never, ex-smoker or current smoker. Alcohol consumption had four categories: never, ex-drinker, occasional drinker or current-drinker. Foods that may influence hypertension (deep fried, instant, roast or smoked, soybean products and soft drinks) and Western-style fast foods were assessed for consumption frequency. Fruit and vegetable consumption were recorded as standard serves eaten per day.

### 2.4. Statistical Analyses

We performed all analyses using SPSS software. Hypertension incidence and 95% CI were calculated for each value of each categorical variable. For statistical inference, all p values were two tailed and significance was set at 5%.

In a large study of an uncommon disease (incidence less than 10%) relative risks (RRs) can be accurately estimated as odds ratios (ORs) [29]. 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 multivariate logistic regression ORs controlled for confounding by age, sex, marital status, socioeconomic status (SES), BMI, underlying diseases and personal behaviours (cigarette smoking and alcohol drinking). A co-variable was included in the multivariable 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.

## 3. Results

### 3.1. Baseline characteristics

Overall, 42785 of the original cohort participated in the 8-year follow up. Of these cohort members 40548 had self-reported as normotension in 2005 are shown in Table1. The mean age at baseline of these longitudinal participants was 32 years and there were more females than males (56% vs 44%). The highest proportion of participants resided in the Central and North-eastern regions and the lowest proportion lived in the East. Sixty three percent of the participants lived in urban areas. More than half of participants had a higher education attainment than high school and their monthly incomes were lower than 10000 baht. The distribution of household assets of participants was quite similar with a slightly higher proportion of participants in the low category. Fifty-four percent of participants had a'normal' BMI and the 'overweight' and 'obese' were about 16%, followed by 'underweight' for 13%. Participants with diabetes and high lipids were 0.8% and 9.8% respectively while those with kidney disease were 2.5%. The ex- smoker participants were 16.8% while current smokers were 8%. The occasional drinkers were 58.3% while regular-drinkers and ex-drinkers were 4.6 and 8.3 respectively.

### 3.2. BMI and incidence and risks of hypertension

The age and multivariable adjusted association between baseline BMI and hypertension incidence by 2013 are shown in Table2 and Fig.1. Overall, the risk of hypertension increased with an increased BMI. The risk of hypertension (aRR=1.89, 95% CI 1.54-2.32) rose above a value of 1 starting with the third ordinal category of BMI (20.75 ≤ BMI < 23) when compared to those with normal BMI (second ordinal category18.5 ≥ BMI < 20.75) or those underweight. An exponential increase in hypertension risk followed in all the subsequent (increasing) categories of BMI. Also noteworthy, comparing to participants with normal BMI (18.5 ≥ BMI<20.75), those with BMI (23.0 ≤ BMI < 25.0) had a risk of incidence of hypertension about three times (aRR = 2.95, 95% CI 2.4-3.62).

## 4. Discussion

This is the first large nationwide cohort study to investigate the incidence of hypertension associated with overweight and obesity in Thai adults. The 8-year follow up from 2005 to 2013 of participants initially normotensive revealed a cumulative incidence of hypertension over this period of 5.1% with 7.1% in men and 3.6% in women. Ageing and obesity were

**Table 1.** Characteristics of 40548 normotensive participants at the 2005 Thai Cohort Study baseline

| Factor | Participants | | | |
|---|---|---|---|---|
| | n | % | HT(n) | I[a]%(95% CI) |
| **Demographic data** | | | | |
| Participants | 40548 | 100 | 1958 | 5.1 (4.9-5.3) |
| Age (y) mean | 32.10 | | | |
| (SD) | (8.2) | | | |
| **Age group** | | | | |
| ≤30 y | 6852 | 40.8 | 208 | 3.2 (2.6-3.4) |
| 31-40 y | 6360 | 37.9 | 444 | 7.0 (6.4-7.6) |
| >40 y | 3590 | 21.4 | 537 | 15.0 (13.8-16.1) |
| **Sex** | | | | |
| Male | 17769 | 43.8 | 1189 | 7.1 (6.7-7.5) |
| Female | 22779 | 56.2 | 769 | 3.6 (3.3-3.8) |
| **Married/partnered** | | | | |
| No | 20586 | 52.1 | 517 | 7.1 (6.7-7.4) |
| Yes | 18946 | 47.9 | 1371 | 2.9 (2.6-3.1) |
| **Regions** | | | | |
| Bangkok | 6522 | 16.2 | 378 | 6.1 (5.5-6.7) |
| Central | 9630 | 23.9 | 476 | 5.2 (4.8-5.7) |
| North | 8125 | 20.0 | 422 | 5.5 (5.0-6.0 |
| North-east | 8580 | 21.3 | 389 | 4.8 (4.4-5.3) |
| East | 2348 | 5.8 | 112 | 5.0 (4.1-5.9) |
| South | 5122 | 12.6 | 167 | 3.5 (2.9-4.0) |
| **Urbanization status**[a] | | | | |
| Rural–rural (RR) | 2508 | 19.1 | 127 | 5.5 (4.5-6.4) |
| Rural–urban (RU) | 3782 | 28.9 | 152 | 4.3 (3.6-5.0) |
| Urban–rural (UR) | 2346 | 17.9 | 147 | 6.7 (5.6-7.7) |
| Urban–urban (UU) | 4461 | 34.1 | 271 | 6.4 (5.7-7.1) |
| **Socioeconomic status** | | | | |
| **Education level** | | | | |
| High school | 17837 | 44.1 | 923 | 5.6 (5.2-5.9) |
| Diploma | 10862 | 26.9 | 445 | 4.3 (3.9-4.7) |
| University | 11753 | 29.1 | 580 | 5.1 (4.7-5.5) |
| **Personal monthly income (baht)** [c] | | | | |
| ≤7000 | 14663 | 36.9 | 417 | 3.0 (2.6-3.3) |
| 7001–10000 | 9214 | 23.2 | 364 | 4.2 (3.6-4.6) |
| 10001–20000 | 11107 | 27.9 | 675 | 6.4 (5.9-6.8) |
| >20000 | 4785 | 12.0 | 476 | 10.3 (9.5-11.2) |
| **Household assetse (baht)**[d] | | | | |
| Low | 15133 | 37.5 | 509 | 3.6 (3.3-3.9) |
| Medium | 12865 | 31.9 | 604 | 4.9 (4.6-5.3) |
| High | 12387 | 30.7 | 836 | 7.1 (6.6-7.5) |

[a]Incidence of Hypertension

[b]Location of residence (rural, R, or urban, U) before and in 2005. The values showed only participants who moved their residences within 5 years.

[c]At the time of the survey in 2005, US1 = 31 Thai baht

[d]Replacement value in Thai baht, categorized into three groups: low ≤ 30, 000, medium 30,001-60,000 and high >60,000

**Table 1.** (continued...)

| Factor | Participants | | | |
|---|---|---|---|---|
| | n | %kg/m$^2$ | HT(n) | I$^a$(95%CI) |
| **BMI classification**[b] | | | | |
| Underweight (BMI < 18.5) | 5252 | 13.0 | 53 | 1.1 (0.8-1.3) |
| Normal (18.5 ≤ BMI < 23) | 21915 | 54.0 | 571 | 2.8 (2.5-3.0) |
| Overweight (23 ≤ BMI < 25) | 6561 | 16.4 | 457 | 7.4 (6.7-8.0) |
| Obese (BMI ≥ 25) | 6314 | 15.6 | 849 | 14.2 (13.3-15.1) |
| **Underlying diseases** | | | | |
| **Diabetes mellitus (type 1&2)** | | | | |
| No | 40209 | 99.2 | 1889 | 5.0 (4.8-5.18) |
| Yes | 339 | 0.8 | 69 | 22.0 (17.4-26.7) |
| **High lipids** | | | | |
| No | 36592 | 90.2 | 1484 | 4.3 (4.07-4.5) |
| Yes | 3956 | 9.8 | 474 | 12.7 (11.6-13.8) |
| **Kidney disease** | | | | |
| No | 39540 | 97.5 | 1875 | 5.0 (4.8-5.2) |
| Yes | 1008 | 2.5 | 83 | 8.9 (7.1-10.7) |
| **Personal behaviours** | | | | |
| **Smoking status** | | | | |
| Never | 29467 | 72.7 | 1127 | 4.0 (3.8-4.3) |
| Ex-smoker | 6824 | 16.8 | 510 | 7.9 (7.3-8.6) |
| Cur-smoker[c] | 3226 | 8.0 | 254 | 8.5 (7.5-9.5) |
| **Drinking status** | | | | |
| Never | 11204 | 27.6 | 419 | 3.9 (3.6-4.3) |
| Ex-drinker | 3365 | 8.3 | 192 | 6.1 (5.3-7.0) |
| Occ- drinker[d] | 23638 | 58.3 | 1125 | 5.0 (4.7-5.3) |
| Reg- drinker[e] | 1868 | 4.6 | 198 | 11.3 (9.8-12.8) |
| **Food consumption habit** | | | | |
| **Instant food** | | | | |
| <1 time/m | 8470 | 20.9 | 502 | 6.3 (5.7-6.8) |
| 1-3 times/m | 16247 | 40.1 | 793 | 5.2 (4.8-5.5) |
| 1-2 times/wk | 9883 | 24.4 | 400 | 4.3 (3.8-4.7) |
| 3-6 times/wk | 4803 | 11.8 | 209 | 4.6 (4.0-5.2) |
| ≥ 1 times/d | 864 | 2.1 | 40 | 4.9 (3.4-6.4) |
| **Soft drink** | | | | |
| <1 time/m | 10970 | 27.1 | 521 | 5.0 (4.6-5.5) |
| 1-3 times/m | 11831 | 29.2 | 547 | 4.9 (4.5-5.3) |
| 1-2 times/wk | 8883 | 21.9 | 433 | 5.1 (4.7-5.6) |
| 3-6 times/wk | 6118 | 15.1 | 317 | 5.5 (4.9-6.1) |
| ≥ 1 times/d | 2401 | 5.9 | 123 | 5.4 (4.4-6.3) |

[a]Incidence of Hypertension
[b]Asian standard BMI classification
[c]Current-smoker
[d]Occasional drinker
[e]Regular drinker

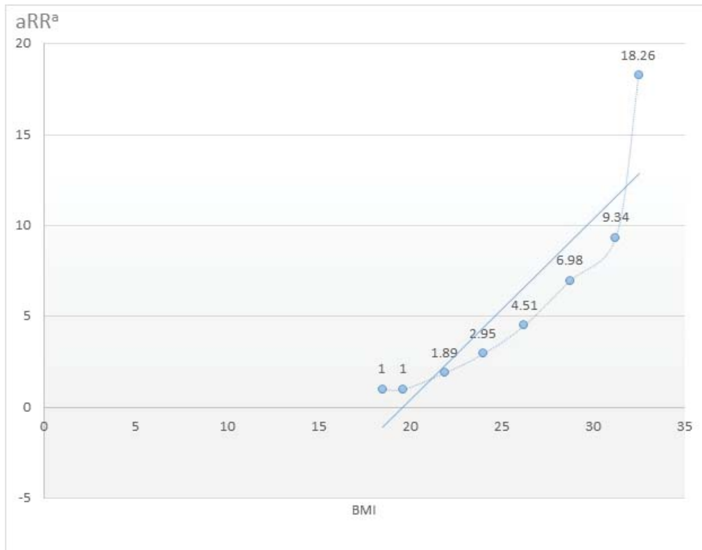


**Figure 1**: Adjusted relative risks of hypertensionby body mass index (Use data from table 2 model 2aRRb plot graph) aRR[a] is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age, sex, marital status, socioeconomic status (exclude type of house), BMI classification, sedentary habits, physical activities, underlying diseases and personal behaviours.

**Table 2.** Association between baseline body mass index and eight-year incidence of hypertension.

| Body Mass Index (kg/m$^2$) at baseline in 2005 | HT(n) | Incident case by 2013[a] I[a] %(95% CI) | Adjusted RR estimates relating BMI and HT | |
|---|---|---|---|---|
| | | | Model 1[b] aRR[d] (95% CI) | Model 2[c] aRR[d] (95% CI) |
| **BMI**[a] | | | | |
| BMI <18.5 | 81 | 1.5 (1.1-1.8) | 1.01 (078-1.33) | 1.0 (0.74-1.35) |
| 18.5 ≤ BMI < 20.75 | 174 | 1.6 (1.4-1.9) | 1 | 1 |
| 20.75≤ BMI < 23.0 | 397 | 4.0 (3.6-4.4) | 2.03 (1.69-2.43) | 1.89 (1.54-2.32) |
| 23.0≤ BMI < 25.0 | 462 | 7.4 (6.8-8.1) | 3.26 (2.72-3.91) | 2.95 (2.4-3.62) |
| 25.0≤ BMI < 27.5 | 431 | 11.8 (10.7-12.8) | 5.27 (4.38-6.34) | 4.51 (3.65-5.56) |
| 27.5≤ BMI < 30.0 | 223 | 15.7 (13.8-17.6) | 7.39 (5.98-9.14) | 6.98 (5.51-8.84) |
| 30.0≤ BMI < 32.5 | 111 | 19.5 (16.2-22.7) | 10.48 (8.06-13.63) | 9.34 (6.98-12.51) |
| BMI ≥32.5 | 79 | 26.8 (21.7-31.9) | 18.79 (13.81-25.57) | 18.26 (12.93-25.78) |

[a]Incidence of Hypertension

[b]Model1 is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age.

[c]Model2 is adjusted relative risks were calculated from multi-variable logistic regression models of hypertension adjusted for age, sex, marital status, socioeconomic status (exclude type of house), BMI classification, sedentary habits, physical activities, underlying diseases and personal behaviours.

[d]Adjusted relative risk

strongly associated with a higher incidence of hypertension. Our study revealed that compared to the participants with normal BMI ($18.5 \leq$ BMI $< 20.75$), those who have marginally higher BMI ($20.75 \leq$ BMI $< 23.0$) and ($23.0 \leq$ BMI $< 25.0$) significantly increased their risk of incidence of hypertension to approximately two and three times respectively. This study found that BMI ($18.5 \leq$ BMI $< 23$ kg/m$^2$), the normal range announced by WHO for Asian population; significantly increased risk of incidence of hypertension by two times compared to those with BMI below 20.75 kg/m$^2$. In addition, the BMI ($18.5 \leq$ BMI $< 25.0$) at the healthy range for Caucasian population strongly increases risk of incidence of hypertension in Thai people.

Our study confirmed that BMI was directly associated with the incidence of hypertension which is consistent with many studies in Asian such as in Korea [30], China [31] and India [32]. We reported that risk of incidence hypertension increased at BMI that considered to be in the normal range for Caucasian people (< 25 kg/m$^2$). It is consistent with previous studies which suggested that for Asian population, a BMI cut-off for cardiovascular risk should be less than 23 kg/m$^2$for overweight and 25 kg/m$^2$ for obesity [16, 33-35]. This result is comparable to the study in the US which reported that in Chinese Americans the corresponding BMI values were 20.9 kg/m$^2$ (CI, 19.7% to 22.1%) for the equivalent of the prevalence of metabolic abnormality in American whites at the BMI of 25 kg/m$^2$ [36].

The risk of hypertension may result from the effect of the amount of body fat. A study in African women in the US showed that body adiposity especially central adiposity was directly and significantly associated with an increased incidence of hypertension [32]. Further, a longitudinal study in Spain reported that body adiposity index was directly associated with an incidence of hypertension so it can be an alternative predictor of hypertension [37]. In addition, the studies showed that the relationship of BMI and body fat may differ between ethnic population [22]. At a similar BMI, Asians tend to have a higher body fat than Europeans [38, 39] especially for abdominal and visceral fat compared to that of Caucasians [40]. At the same amount of body fat percentage, BMI of Indonesians tended to have a two points lower than that of Dutch Caucasians [22]. Moreover, the Singaporean BMI cut-off points for overweight should be lower by 2 – 3 points than WHO recommendation for Asian population [18, 19].

This study has many strengths. To our knowledge, it is the first 8-year longitudinal study of risks of hypertension with a large number of Thai participants. Moreover, most risk factors for hypertension were analysed as well. TCS participants live all over Thailand so the study represents the Thai population well in social geography and socio-economy [25]. Therefore, the results of this 8-year study will be quite accurate despite losing some statistical power due to cohort attrition. Worldwide many studies report on BMI cut-off point for risk for hypertension however socio-economic, lifestyle and behaviour risks and ethnicity of each country are not similar. The results from our cohort will prevent incidence of hypertension in Thailand.

However, there are many limitation for our study. All data are self-reported so there may be some recalled error. Validation of self-reported weight, height and body mass index revealed that accuracy was acceptable [26]. Also we performed a validation study of self-reported hypertension using a random age-sex matched sample of the cohort reporting hypertension (n=240) or no hypertension (n=240) [41]. The study found that self-report of hypertension yes/no status was high for accuracy at 82% (yes) and 86% (no) respectively. We also 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 [42]. In addition, the attrition over 8-year followed up was 50%.

## 5. Conclusion

Our study concludes that lowering BMI cut-off point by two points for the risk threshold of hypertension is very important for the Thai population since we found that the incidence and risk of hypertension at the BMI ($20.75 \leq$ BMI $< 23.0$) was already too high. Therefore, people need to be aware that preventing hypertension, needs BMI to be at a lower point (< 21 kg/m$^2$) than the level used at present (< 23.0 kg/m$^2$). In Thailand, obesity, an important risk factor for many chronic diseases, is already high in prevalence so long term policies for preventing obesity from childhood should be developed by Ministry of Public health. Further study for BMI cut-off point for risk of hypertension should be performed in other Asian countries as well.

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## Ethical Considerations

Ethical approval was obtained from Sukhothai Thammathirat Open University Research and Development Institute (protocol 0522/10) and the Australian National University Human Research Ethics Committee (protocol 2004344 and 2009570). Informed, written consent was obtained from all participants.

## References

[1] J. Zhao , S.A. Seubsman, A. Sleigh, Thai Cohort Study Team T. Timing of urbanisation and cardiovascular risks in Thailand: evidence from 51 936 members of the thai cohort study, 2005-2009, J Epidemiol 24(2014) 484-93.

[2] T. L. Kjellstrom, A. Sleigh, S. Khamman, S. Seubsman, J. Dixon, et al. Associations between urbanisation and components of the health-risk transition in Thailand. A descriptive study of 87,000 Thai adults, Glob Health Action 2(2009).

[3] V. Yiengprugsawan, B. K. Caldwell, L. L. Lim,S. A. Seubsman, A. C. Sleigh, Lifecourse Urbanization, Social Demography, and Health Outcomes among a National Cohort of 71,516 Adults in Thailand, International Journal of Population Research (2011).

[4] C. Arambepola, S. Allender, R. Ekanayake,D. Fernando, Urban living and obesity, is it independent of its population and lifestyle characteristics? Tropical medicine & international health, TM & IH, 13(2008) 448-57.

[5] C. Angkurawaranon, W. Jiraporncharoen, B. Chenthanakij, P. Doyle, D. Nitsch, Urban environments and obesity in southeast Asia: a systematic review, meta-analysis and meta-regression, PloS one 9(2014).

[6] A. C. Sleigh, S. A. Seubsman, C. Bain, Thai Cohort Study T. Cohort profile, The Thai Cohort of 87,134 Open University students, Int J Epidemiol 37(2008) 266-72.

[7] P. Thawornchaisit, F. de Looze, C. M. Reid, S. A. Seubsman, A. C. Sleigh, T. Thai Cohort Study, Health risk factors and the incidence of hypertension, 4-year prospective findings from a national cohort of 60 569 Thai Open University students, BMJ open 25(2013).

[8] P. Thawornchaisit, F. de Looze, C. M. Reid, S. A. Seubsman, T. T. Tran, Sleigh A. Health-Risk Factors and the Prevalence of Chronic Kidney Disease, Cross-Sectional Findings from a National Cohort of 87,143 Thai Open University Students, Global Journal of Health Science 24(2015) 59-72.

[9] P. Thawornchaisit, F. de Looze, C. M. Reid, S. A. Seubsman, A. C. Sleigh, Thai Cohort Study T. Health-Risk Transition and 8-Year Hypertension Incidence in a Nationwide Thai Cohort Study, GJHS 10(2018) 15.

[10] J. J. Noubiap, M. Essouma, J. J. Bigna, A. M. Jingi, L. N. Aminde, J. R. Nansseu, Prevalence of elevated blood pressure in children and adolescents in Africa: a systematic review and meta-analysis, The Lancet Public health 2(2017) 375-86.

[11] H. M. Shihab, L. A. Meoni, A. Y. Chu, N. Y. Wang, D. E. Ford, K. Y. Liang, et al. Body mass index and risk of incident hypertension over the life course: the Johns Hopkins Precursors Study, Circulation 18(2012) 2983-9.

[12] P. Thawornchaisit, F. de Looze, C. M. Reid, S. A. Seubsman, A. Sleigh, T. Thai Cohort Study, Health-risk factors and the prevalence of hypertension cross-sectional findings from a national cohort of 87,143 Thai Open University students, Global Journal of Health Science 5(2013) 126-41.

[13] M. Kanazawa, N. Yoshiike, T. Osaka, Y. Numba, P. Zimmet, S. Inou, Criteria and classification of obesity in Japan and Asia-Oceania, World review of nutrition and dietetics (2005) 1-12.

[14] W. H. O. E. Consultation, Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies, Lancet. (2004) 157-63.

[15] M. A. Hussain, A. A. Mamun, C. Reid, R. R. Huxley, Prevalence, Awareness, Treatment and Control of Hypertension in Indonesian Adults Aged >/=40 Years Findings from the Indonesia Family Life Survey (IFLS), PloS one (2016).

[16] L. J. Gray, T. Yates, M. J. Davies, E. Brady, D. R. Webb, N. Sattar, et al. Defining obesity cut-off points for migrant South Asians, PloS one (2011).

[17] N. Misra, L. Khurana, Obesity-related non-communicable diseases: South Asians vs White Caucasians, Int J Obes (Lond). (2011) 167-87.

[18] M. Deurenberg-Yap, S. K. Chew, V. F. Lin, B. Y. Tan, W. A. van Staveren, P. Deurenberg, Relationships between indices of obesity and its co-morbidities in multi-ethnic Singapore, Int J Obes Relat Metab Disord. 25(2001) 1554-62.

[19] M. Deurenberg-Yap, G. Schmidt, W. A. van Staveren, P. Deurenberg, The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore, Int J Obes Relat Metab Disord. 24(2000) 1011-7.

[20] L. L. Moore, A. J. Visioni, M. M. Qureshi, M. L. Bradlee, R. C. Ellison, D'Agostino R. Weight loss in overweight adults and the long-term risk of hypertension: the Framingham study, Arch Intern Med. (2005) 1298-303.

[21] V. J. Stevens, E. Obarzanek, N. R. Cook, I. M. Lee, L. J. Appel, D.Smith West, et al, Long-term weight loss and changes in blood pressure: results of the Trials of Hypertension Prevention, phase II, Ann Intern Med. (2001) 1-11.

[22] T. Shrout, D. W. Rudy, M. T. Piascik, Hypertension update, JNC8 and beyond, Curr Opin Pharmacol (2017) 41-6.

[23] World Health Organization. The top 10 causes of death, (2018). Available from: http://wwwwhoint/news-room/fact-sheets/detail/the-top-10-causes-of-death.

[24] B. M. Egan, Y. Zhao, R. N. Axon, US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008, JAMA (2010) 2043-50.

[25] S. A. Seubsman, V. Yiengprugsawan, A. C. Sleigh, the Thai Cohort Study T. A large national Thai Cohort Study of the Health-Risk Transition based on Sukhothai Thammathirat Open University students, ASEAN journal of Open and Distance Learning 4(2012).

[26] Lim, S. Seubsman, A. Sleigh, Validity of self-reported weight, height, and body mass index among university students in Thailand: Implications for population studies of obesity in developing countries, Population health metrics 7(2009) 15.

[27] Australian Institute of Health and Welfare. The Active Australia Survey: a guide and manual for implementation, analysis and reporting Canberra. AIHW (2003).

[28] E. Banks, L.Lim, S. A. Seubsman, C. Bain, A. Sleigh, Relationship of obesity to physical activity, domestic activities, and sedentary behaviours: cross-sectional findings from a national cohort of over 70,000 Thai adults, BMC Public Health. (2011)

762.
[29] P. Webb, C. Bain, Essential Epidemiology: An Introduction for Students and Health Professionals. 2 ed: Cambridge University Press, (2011).
[30] J. W. Lee, N. K. Lim, T. H. Baek, S. H. Park, H. Y. Park, Anthropometric indices as predictors of hypertension among men and women aged 40-69 years in the Korean population: the Korean Genome and Epidemiology Study, BMC Public Health (2015) 140.
[31] W. Aekplakorn, Thai national Health Examination Survey, V, (2016). Available from: http://www.thaiheartorg/images /column_1387023976/NHES5_EGATMeeting13Dec13.pdf
[32] M. Zhang, Y. Zhao, H. Sun, X. Luo, C. Wang, L. Li, et al, Effect of dynamic change in body mass index on the risk of hypertension: Results from the Rural Chinese Cohort Study, Int J Cardiol (2017) 117-22.
[33] A. V. Chobanian, G. L. Bakris, H. R. Black, W. C. Cushman, L. A. Green, J. L. Izzo, Jr., et al. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, Hypertension (2003) 1206-52.
[34] A. Misra, Ethnic-Specific Criteria for Classification of Body Mass Index: A Perspective for Asian Indians and American Diabetes Association Position Statement, Diabetes technology & therapeutics (2015) 667-71.
[35] P. Huai, H. Xun, K. H. Reilly, Y. Wang, W. Ma, B. Xi, Physical activity and risk of hypertension: a meta-analysis of prospective cohort studies. Hypertension (2013) 1021-6.
[36] U. P. Gujral, E. Vittinghoff, M. Mongraw-Chaffin, D. Vaidya, N. R. Kandula, M. Allison, et al, Cardiometabolic Abnormalities Among Normal-Weight Persons From Five Racial/Ethnic Groups in the United States: A Cross-sectional Analysis of Two Cohort Studies. Ann Intern Med. (2017) 628-36.
[37] A. E. Field, T. Byers, D. J. Hunter, N. M. Laird, J. E. Manson, D. F. Williamson, et al, Weight cycling, weight gain, and risk of hypertension in women, Am J Epidemiol. (1999) 573-9.
[38] Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration. Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment, Lancet Diabetes Endocrinol 8(2014) 634-47.
[39] P. Vathesatogkit, M. Woodward, S. Tanomsup,B. Hengprasith, W. Aekplakorn, S. Yamwong, et al, Long-term effects of socioeconomic status on incident hypertension and progression of blood pressure (2012).
[40] G. Hu, N. C. Barengo, J. Tuomilehto, T. A. Lakka, A. Nissinen, P. Jousilahti, Relationship of physical activity and body mass index to the risk of hypertension: a prospective study in Finland, Hypertension (2004) 25-30.
[41] P. Thawornchaisit, F. De Looze, C. M. Reid, S.A. Seubsman, A. Sleigh, T. Thai Cohort Study, Validity of self-reported hypertension: findings from the Thai Cohort Study compared to physician telephone interview, Global journal of health science (2013) 1-11.
[42] K. Thinkhamrop, S. Seubsman, A. Sleigh, Reasons for Non-Response to Mailed Questionnaires—experience of a large Cohort Study in Thailand, KKU J Public Health Res. 4(2011) 73-87.