Secular changes and predictors of adult height for 86,105 male and female members of the Thai Cohort Study born between 1940 and 1990

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ABSTRACT

Background Height trends can be useful indicators of population health, but despite Thailand’s rapid socioeconomic development since the 1950s, few studies have examined accompanying secular changes in adult height or the effects of the transition on the heights of rural versus urban populations. This study therefore sought to document average heights in different age groups of rural and urban Thais and to investigate factors associated with attained height.

Methods Data from 86,105 Thai Cohort Study participants was used to estimate mean heights for men and women in different birth year groups. Simple linear regression was used to calculate the change in height per decade of birth year among those based in rural or urban locations as children. Multiple linear regression was used to investigate effects of other childhood factors on height.

Results Overall, average heights were found to have increased by approximately 1 cm per decade in those born between 1940 and 1990. However, the rate of increase was 0.4–0.5 cm per decade greater among urban-based Thais compared with those from the countryside. Parental education levels, household assets, birth size, sibling number, birth rank and region of residence were also significantly associated with adult height.

Conclusions These data suggest a marked secular increase in Thai heights in the second half of the 20th century probably reflecting improved child health and nutrition over this time. Rural-born Thais, who benefited to a lesser extent from the changes, may face future health challenges with greater risks of, among other things, obesity and its health consequences.

METHODS

The overall aim of the Thai Cohort Study is to examine the health consequences of Thailand’s rapid socioeconomic development and environmental change. To this end, participants were recruited from the student body of the Sukhothai Thammathirat Open University (STOU). STOU students reside all over Thailand and have a modest socioeconomic status. Many are rural dwellers and most have full-time jobs. In 2005, all STOU students who had completed at least their first semester of study (approximately 200,000) were mailed a questionnaire, information sheet and consent form. A total of 87,134 students (47,514 women and 39,820 men) returned completed questionnaires (44%). Participants were asked to record their height in centimetres (cm). We also requested information on factors related to socioeconomic status during childhood, including the area (rural or urban) in which they resided as a child (aged 10–12 years). The sensitive period for socioeconomic influences on height may be earlier than age 10–12 years, but this age was specified for greater accuracy of recall.

Statistical analyses Analyses were conducted separately for men and women. As we were interested in comparing heights across different age groups, participants were initially grouped by birth year. Participants’ ages ranged from 15 to 87 years, so we excluded...
those aged over 65 years (n=76) to avoid a long tail in the first birth year category. Mean heights (cm) with 95% CI were calculated for each group. A similar comparison was made stratifying by area of residence (rural/urban) at age 10–12 years. The data were further assessed using simple linear regression with height as the outcome and mean-centred birth year (in decades) as the predictor. Stratification of these models by childhood area of residence suggested effect modification, so an interaction term for birth year and area of residence was added to the original model. Other childhood factors associated with attained adult height were assessed using multiple linear regression. All variables related to childhood circumstance were entered into the model, including: attained maternal and paternal level of education; sibling number; birth rank; birth size; whether breast fed in infancy; and the numbers of material resources in the home such as electricity, radio, television or a refrigerator at age 10–12 years. Variables relating to current circumstances (such as current income) were excluded to minimise the possibility of reverse causation.

We had two possible measures of birth size: self-reported birth weight (g) and relative birth size recalled by relatives (small, normal, large). When both questions were answered, the two measures were highly correlated, but the data for both were missing for a large proportion of participants. More (75% vs 40%) responded to the question on birth size recalled by relatives than on birth weight, so we used the former to estimate the effect on height change. Because a large amount of birth size data was missing we have reported the estimates for other childhood factors unadjusted for birth size. Of note, the only estimate materially changed by the addition of birth size to the model was that for breast feeding.

Birth rank was initially analysed in strata of number of siblings and age groups. The results from stratified analyses were similar to unstratified analyses and suggested that those later born were more likely to be taller than those first born, thus only a term for first born versus later born was included in the final model.

A variable indicative of childhood material resources was created by summing the positive responses from the following question: ‘Which of the following did your home have when you were 10–12 years old? Electricity (generator or outside line), microwave, refrigerator, electric fan, air conditioning, television, video/tape/CD player, computer, telephone, mobile telephone, water heater, or washing machine?’

Ethics 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). Informed written consent was obtained from all participants.

RESULTS
Overall, 86 105 participants (99% of all cohort members) aged under 66 years reported their height. Table 1 shows the frequencies of various demographic factors as well as the indicators of childhood circumstances.

We found among both female and male participants that height increased with later birth year (table 2).

For women, those born between 1986 and 1990 were almost 3 cm taller than women born between 1940 and 1956. Similarly, men born between 1986 and 1990 were on average 4 cm taller than men born between 1940 and 1956. This difference was even greater when considered jointly with area of residence at age 10–12 years (table 3): the youngest group of urban-based men was on average 6.4 cm taller than the oldest group of rural-based men and the equivalent difference for women was 4.3 cm.

Mean heights with 95% CI for men (figure 1A) and women (figure 1B) by rural/urban location at age 10–12 years are shown in figure 1. Linear regression suggested an overall increase in height of 1.50 cm (95% CI 1.36 to 1.63) per decade for male urban dwellers compared with 1.01 cm (95% CI 0.95 to 1.09) per decade for male rural dwellers. For women the estimates were 1.32 cm (95% CI 1.20 to 1.43) for urban dwellers and 0.91 cm (95% CI 0.82 to 0.99) for rural dwellers. The interaction terms for birth year and area of residence (rural/urban) aged 10–12 years were highly significant for both men and women (p<0.0001).

Table 4 shows the estimates of effect on height change of various measures of childhood circumstances. Participants’ birth year remained a significant predictor of height after adjustment for the measured childhood factors, with approximately half a centimetre increase in height per decade for both women and men.

Several other childhood factors were significantly associated with attained adult height. Educational attainment of both parents was related to height of both men and women. Maternal education level was more important for women, such that those with mothers with tertiary education were on average 1.1 cm (95% CI 0.7 to 1.5 cm) taller than those whose mothers had no formal education; for men, paternal level of education was associated with the larger effect, such that men whose fathers had tertiary education were on average 1.4 cm (95% CI 1.0 to 1.8 cm) taller than men whose fathers had no formal education. Of the factors considered, birth size (recalled by relatives) was associated with the largest effects on height for both sexes. Women who were considered large or overweight at birth were on average approximately 2.8 cm taller than those considered small or underweight at birth, and the corresponding estimate for men was 3.3 cm. Those who reported having been breast fed were on average approximately 0.3 cm taller than those who reported they were not breast fed, although this effect disappeared when birth size was added to the model (0.05 cm; 95% CI −0.18 to 0.27 for women and −0.01 cm; 95% CI −0.33 to 0.31 for men). Having larger numbers of siblings was associated with shorter stature, with a more pronounced effect in men than women. Birth order was also important with both later born men and women tending to be taller than those first born. In both sexes, those with a larger number of assets in the home at age 10–12 years were on average taller than those who had few assets, although the effect was not as large in women. As some of the technologies included in the assets score did not exist when the older participants were children, in addition to adjusting for birth year, we also stratified by birth year group. The same pattern was evident for all groups (results not shown) so we have presented only the birth year adjusted estimates.

DISCUSSION
Using data from 86 105 Thai open university students we have found evidence of a substantial increase in average attained adult height among both men and women born between 1940 and 1990, amounting overall to approximately 1 cm increase in height per decade. A rural/urban difference was strikingly evident such that the rate of increase in height has been approximately 0.5 cm per decade greater among men reared in urban areas compared with those from rural areas and 0.4 cm per decade greater for urban compared with rural women. Multivariable analyses showed that other indicators of childhood circumstances (such as current income) were not significantly associated with height.
Table 1 Frequencies of demographic and childhood characteristics for female and male Thai Cohort Study participants with recorded height

| Birth year | Women N=47207 | Men N=38898 |
|------------|---------------|-------------|
| 1940–55    | 564 (1.2%)    | 1412 (3.6%) |
| 1956–65    | 4401 (9.3%)   | 6336 (16.2%)|
| 1966–75    | 13438 (28.47%)| 13565 (34.87%)|
| 1976–85    | 27148 (57.51%)| 16746 (43.05%)|
| 1986–90    | 1636 (3.47%)  | 839 (2.16%)  |

Current area of residence

| Area of residence | Women N=47207 | Men N=38898 |
|-------------------|---------------|-------------|
| Rural             | 22041 (47.01%)| 19211 (49.76%)|
| Urban             | 24042 (52.99%)| 19399 (50.24%)|

Current area of residence age 10

| Area of residence | Women N=47207 | Men N=38898 |
|-------------------|---------------|-------------|
| Bangkok           | 9058 (19.32%) | 5618 (14.57%)|
| Central           | 12187 (26.00%)| 8740 (22.76%)|
| North             | 8021 (17.11%) | 7566 (20.24%)|
| Northeast         | 8410 (17.94%) | 9411 (24.41%)|
| East              | 2909 (6.21%)  | 2364 (6.13%)  |
| South             | 6290 (13.42%) | 4860 (12.61%)|

Current monthly income (Baht)

| Income (Baht) | Women N=47207 | Men N=38898 |
|---------------|---------------|-------------|
| <3000         | 4842 (10.52%) | 4412 (11.63%)|
| 3001–7000     | 16976 (36.88%)| 9000 (23.72%)|
| 7001–10000    | 10887 (23.65%)| 8735 (23.02%)|
| 10001–20000   | 9551 (20.75%) | 9511 (20.75%)|
| 20001–30000   | 2325 (5.05%)  | 2900 (7.64%)  |
| >30000        | 1446 (3.14%)  | 2142 (5.64%)  |

Level of education

| Father’s levels of education | Women N=47207 | Men N=38898 |
|------------------------------|---------------|-------------|
| No formal education          | 2353 (5.07%)  | 2432 (6.37%) |
| Primary level                | 28158 (60.72%)| 23613 (61.84%)|
| Secondary level              | 9249 (19.94%) | 7031 (18.41%)|
| Tertiary level               | 3958 (8.54%)  | 3085 (8.08%)|
| Do not know                  | 2655 (5.73%)  | 2021 (5.29%)|

| Mother’s level of education | Women N=47207 | Men N=38898 |
|-----------------------------|---------------|-------------|
| No formal education         | 4433 (9.48%)  | 4258 (11.08%)|
| Primary level               | 33583 (71.81%)| 27608 (71.83%)|
| Secondary level             | 4510 (9.64%)  | 3146 (8.18%)|
| Tertiary level              | 2544 (5.44%)  | 1839 (4.78%)|
| Do not know                 | 1697 (3.63%)  | 1586 (4.13%)|

| Number of siblings | Women N=47207 | Men N=38898 |
|--------------------|---------------|-------------|
| 0                  | 2218 (4.76%)  | 1361 (3.54%)|
| 1                  | 11375 (24.41%)| 7709 (20.04%)|
| 2                  | 11754 (25.22%)| 8517 (22.14%)|
| 3                  | 7419 (15.92%) | 6099 (15.86%)|
| 4                  | 4621 (9.92%)  | 4359 (11.33%)|
| 5+                 | 9216 (19.78%) | 10416 (27.08%)|

Birth size recalled by relatives

| Birth size recalled | Women N=47207 | Men N=38898 |
|---------------------|---------------|-------------|
| Small or underweight| 9231 (19.79%) | 6265 (16.41%)|
| Normal              | 22201 (47.61%)| 18171 (47.45%)|
| Large or overweight | 4456 (9.55%)  | 3278 (8.56%)|
| Do not know         | 10747 (23.05%)| 10558 (27.57%)|

Breast fed

| Breast fed | Women N=47207 | Men N=38898 |
|------------|---------------|-------------|
| Yes        | 41141 (91.62%)| 34453 (90.47%)|
| No         | 3762 (8.38%)  | 2170 (5.93%)|

Area of residence age 10–12 years

| Area of residence | Women N=47207 | Men N=38898 |
|-------------------|---------------|-------------|
| Rural             | 34711 (74.16%)| 29843 (77.65%)|
| Urban             | 12095 (25.84%)| 8589 (22.35%)|

No of household assets when aged 10–12 years

| No of household assets | Women N=47207 | Men N=38898 |
|------------------------|---------------|-------------|
| 0–1                    | 6369 (13.56%) | 9344 (24.18%)|
To our knowledge only one study has previously published data on secular changes in attained adult height in Thailand. To our knowledge only one study has previously published data on secular changes in attained adult height in Thailand. 

Table 3 Mean height in cms (SD) by age group for men and women according to whether they lived in an urban/rural area aged 10–12 years

| Birth year | Women Rural | Women Urban | Men Rural | Men Urban |
|------------|-------------|-------------|----------|----------|
| 1940–55    | 158.0 (5.4) | 156.5 (5.5) | 166.0 (6.1) | 166.9 (5.8) |
| 1956–65    | 156.3 (5.4) | 156.7 (5.3) | 166.9 (5.8) | 168.5 (5.7) |
| 1966–75    | 156.9 (5.4) | 157.9 (5.6) | 167.6 (5.7) | 168.5 (5.8) |
| 1976–85    | 157.8 (5.6) | 159.3 (5.7) | 168.7 (6.0) | 171.2 (6.0) |
| 1986–90    | 158.5 (5.7) | 160.3 (6.2) | 169.6 (6.2) | 172.4 (6.1) |

Figure 1 Mean heights and 95% CI among (a) Thai men and (b) Thai women who resided in rural or urban locations at age 10–12 years.
lifestyles are increasingly adopted. Our work suggests that this could be of particular concern in rural areas where the relative height deficit combined with an increasingly energy-dense diet and sedentary lifestyle could result in substantial levels of obesity. Recent work based on the Thai National Health Examination Surveys suggest indeed that rates of obesity are increasing more rapidly in rural than urban areas.36 Height is also positively associated with a number of cancers, particularly those of the breast, prostate and colon.9 It is likely, therefore, that rates of these types of cancers (currently relatively rare in Thailand compared with western populations)37 will increase with the increase in average heights.

In conclusion, we have found evidence of a marked secular increase in the height of Thais in the second half of the 20th century reflecting the rapid socioeconomic development of Thailand over this period. While these changes suggest overall

### What this study adds

Average heights increased approximately 1 cm per decade in those born between 1940 and 1990, with urban Thais increasing approximately 0.5 cm more per decade than rural dwellers. Parental education, household assets, birth size, family size and birth rank were also significantly associated with height. This marked secular increase in Thai heights reflects improved child health and nutrition, but rural-born Thais have benefited less.

They still tend to be of modest stature as adults, and now face a nutrition transition with a food surplus, obesity and its consequences.

### Table 4  Adjusted* estimates of height change (cm) for a unit change in factors associated with childhood circumstances among Thais

| Factor                                      | Women Estimate cm | 95% CI       | p Value | Men Estimate cm | 95% CI       | p Value |
|---------------------------------------------|-------------------|--------------|---------|-----------------|--------------|---------|
| Per decade increase in birth year           | 0.67              | 0.58 to 0.76 | <0.0001 | 0.58            | 0.49 to 0.67 | <0.0001 |
| Mother’s education                          |                   |              |         |                 |              |         |
| None                                        | Reference         |              |         | Reference       |              |         |
| Primary                                     | 0.54              | 0.33 to 0.75 | <0.0001 | 0.26            | 0.03 to 0.49 | 0.03    |
| Secondary                                   | 0.74              | 0.46 to 1.02 | <0.0001 | 0.63            | 0.29 to 0.96 | 0.0002  |
| Tertiary                                    | 1.10              | 0.73 to 1.46 | <0.0001 | 0.98            | 0.53 to 1.42 | <0.0001 |
| Father’s education                          |                   |              |         |                 |              |         |
| None                                        | Reference         |              |         | Reference       |              |         |
| Primary                                     | 0.41              | 0.14 to 0.68 | 0.003   | 0.50            | 0.20 to 0.79 | 0.003   |
| Secondary                                   | 0.55              | 0.26 to 0.84 | 0.0002  | 0.86            | 0.64 to 1.29 | <0.0001 |
| Tertiary                                    | 0.65              | 0.29 to 1.01 | 0.0004  | 1.43            | 1.02 to 1.84 | <0.0001 |
| Birth size as recalled by relatives         |                   |              |         |                 |              |         |
| Small or underweight                        | Reference         |              |         | Reference       |              |         |
| Normal                                      | 1.71              | 1.57 to 1.85 | <0.0001 | 1.89            | 1.71 to 2.07 | <0.0001 |
| Large or overweight                         | 2.60              | 2.60 to 3.00 | <0.0001 | 3.30            | 3.04 to 3.57 | <0.0001 |
| Breast fed†                                 |                   |              |         |                 |              |         |
| No                                          | Reference         |              |         | Reference       |              |         |
| Yes                                         | 0.30              | 0.10 to 0.51 | 0.004   | 0.27            | 0.007 to 0.55 | 0.06    |
| No of siblings                              |                   |              |         |                 |              |         |
| 0                                           | Reference         |              |         | Reference       |              |         |
| 1                                           | –0.08             | –0.37 to 0.20 | 0.55 | –0.36            | –0.74 to 0.03 | 0.07    |
| 2                                           | –0.27             | –0.56 to 0.02 | 0.07 | –0.48            | –0.87 to –0.09 | 0.01    |
| 3                                           | –0.39             | –0.70 to –0.09 | 0.01 | –0.75            | –1.16 to –0.34 | 0.003   |
| 4                                           | –0.70             | –1.03 to –0.37 | <0.0001 | –0.84   | –1.26 to –0.41 | 0.0001  |
| 5+                                          | –0.63             | –0.95 to –0.31 | <0.0001 | –1.19   | –1.60 to –0.78 | <0.0001 |
| Birth order                                 |                   |              |         |                 |              |         |
| First born                                  | Reference         |              |         | Reference       |              |         |
| Later born                                  | 0.37              | 0.24 to 0.49 | <0.0001 | 0.31            | 0.16 to 0.46 | <0.0001 |
| Area of residence when aged 10–12 years     |                   |              |         |                 |              |         |
| Urban                                       | Reference         |              |         | Reference       |              |         |
| Rural                                       | –0.73             | –0.88 to –0.59 | <0.0001 | –1.11   | –1.29 to –0.94 | <0.0001 |
| Assets in the home when aged 10–12 years    |                   |              |         |                 |              |         |
| 0–1                                         | Reference         |              |         | Reference       |              |         |
| 2–4                                         | 0.16              | –0.02 to 0.34 | 0.08 | 0.50            | 0.32 to 0.68 | 0.16    |
| 5–6                                         | 0.61              | 0.43 to 0.81 | <0.0001 | 1.19   | 0.98 to 1.39   | <0.0001 |
| >6                                          | 1.40              | 1.16 to 1.64 | <0.0001 | 1.95   | 1.67 to 2.24   | <0.0001 |

*Each factor adjusted for all others listed in the table apart from birth size recalled by relatives.
†Estimates calculated using data from those who reported birth size (~75% of cohort), adjusted for all listed factors.
‡When birth size is added to the model the effect of breast feeding is negligible (0.05 cm, 95% CI –0.18 to 0.27 for women and –0.01 cm, 95% CI –0.33 to 0.31 for men).

### What is already known on this subject

Thailand has undergone rapid socioeconomic development over the past 50 years with associate changes in population health. Secular trends in adult height reveal population health transitions, but such changes in Thailand, particularly urban/rural contrasts, are little studied.
positive health outcomes, they may also reveal opportunities for health interventions, particularly for rural-born Thais who appear to have, at least until the latter part of the 20th century, benefited to a lesser extent from the secular trend in height.

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Competing interests None.

Patient consent Obtained.

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