Patterns and correlates of adult height in Sri Lanka

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ARTICLE INFO
Article history:
Received 1 January 2010
Received in revised form 15 September 2010
Accepted 27 September 2010

Keywords:
Height
Sri Lanka
Secular trends
Physical stature
Health

ABSTRACT
The present study examines patterns and socioeconomic and demographic correlates of adult height among Sri Lankan adults. Data were available for height and socio-demographic factors from a nationally representative cross-sectional sample of 4477 subjects above 18 years. Recruitment was between 2005 and 2006. Mean age of all subjects was 46.1 ± 15.1 years. Mean height of males and females were 163.6 ± 6.9 cm and 151.4 ± 6.4 cm respectively. Mean height showed a significant negative correlation with age (p < 0.001, r = −0.207). Highest mean height in females 154.0 ± 5.9 cm and males 165.6 ± 6.9 cm were observed in those born after 1977. Rural females (151.4 ± 6.2 cm) were significantly taller than the urban (151.3 ± 7.2 cm). However, this was not observed in males. In multivariate analysis, year of birth, level of education and household income were significantly associated with height. Height demonstrated a significant negative correlation with systolic blood pressure (r = −0.032), presence of diabetes (r = −0.069), total cholesterol (r = −0.106), HDL cholesterol (r = −0.142) and LDL cholesterol (r = −0.104). Height was associated with household income and level of education in Sri Lanka and demonstrated a distinct increasing trend over successive generations.

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1. Introduction

Height is considered an important indicator of nutrition and health of a population (Akachi and Canning, 2007; Deaton, 2007). In the last century, a consistent increase in mean height of adults has been found both in the developed and developing countries mirroring the improvements in nutritional (Hoppa and Garlie, 1998) and socio-economic status (Prebeg, 1998; Thomas and Frankenber, 2002; Li et al., 2004). In Europe, height has been increasing in most populations (Garcia and Quintana-Domeque, 2007). However, recent studies have reported that the increase in height has reached a plateau in Germany (Zellner et al., 2004) and Poland (Krawczynski et al., 2003).

An increase in height has been reported from developing countries such as Brazil (Marmo et al., 2004), India (Virani, 2005), Cook Islands (Ulijaszek, 2001), Iran (Ayatollahi et al., 2006), and Mexico (Malina et al., 2004). Studies on secular changes in height in populations are useful for providing information on nutritional status in early life and updating reference standards on growth. It would also provide an insight to the epidemiological trends of cardiovascular disease (Wannamethee et al., 1998; Silventoinen et al., 2006). To our knowledge, there are no published data on adult height in Sri Lanka. Previous studies have been limited to adolescents.

In addition to the secular trends, height has also been known to be associated with the socio-economic status (Mascie-Taylor and Lasker, 2005) and higher intellectual performance (Tuvemoa et al., 1999). Height, a marker of
childhood growth, is associated with lower mortality and morbidity from ischemic heart disease (Williams et al., 1997; McCarron et al., 2002) and associated risk factors (Brown et al., 1991; Langenberg et al., 2003). It is thought that better childhood conditions, such as improved nutrition and fewer respiratory infections, result in both greater adult height and lower rates of ischemic heart disease (Davey Smith et al., 2000).

The present study aims to describe the patterns of height and the underlying socioeconomic and demographic correlates among Sri Lankan adults. We also report the relationship of height with presence of diabetes mellitus, fasting blood glucose, systolic and diastolic blood pressure, lipid parameters and metabolic syndrome.

2. Materials and methods

2.1. Study population and sampling

Sri Lanka (previously known as Ceylon) is an island nation in South Asia, located about 31 km off the southern coast of the Indian Subcontinent. It has a population of about nineteen million people (Department of Census and Statistics Sri Lanka, 2001). Data on height and its correlates were collected as part of a wider national study on diabetes and cardiovascular disease. This cross-sectional study was conducted in seven of the nine provinces (Government of Sri Lanka, 2005) in Sri Lanka between August 2005 and September 2006. The Western, Southern, Sabaragamuwa, Uva, North-Western, Central and North-Central provinces were included while the Northern and Eastern provinces of the country affected by the war at that time had to be excluded from the study. Detailed sampling has been previously reported (Katulanda et al., 2008).

We recruited a nationally representative sample of 5000 non-institutionalized adults ≥18 years-of-age, using a multi-stage random-cluster-sampling technique. Those who were pregnant, acutely ill or declined participation were excluded. The selected households were visited by the study team. Informed consent was obtained from all study participants in each household after providing information before random selection. An eligible adult of age ≥18 years satisfying inclusion criterion was randomly selected from all eligible adults in each consenting household by simple random selection.

2.2. Data collection

Data collection was carried out by a field team of medical graduates and nurses who were trained in research methodology before commencing data collection. Temporary data collection centres were established within each cluster. Height was measured using Harpenden pocket stadiometers (Chasmors Ltd., London, UK) to the nearest 0.1 cm according to the standard methods (World Health Organization, 1995). The data collectors were regularly trained on the measurement techniques to ensure consistency over time and between centres. Stadiometers were checked for accuracy at regular intervals.

Urban and rural sectors were defined according to the classification of the Sri Lanka Department of Census and Statistics, where the urban sector comprised of all municipal and urban council areas (Department of Census and Statistics Sri Lanka, 2001). These areas generally comprise of towns or cities in individual districts closer to major highways with many important government institutions and trade. This classification does not necessarily depend upon the population size although the population density is generally higher in most urban areas compared to rural. Subjects were considered to have ‘diagnosed diabetes’ if they had been previously diagnosed at a government hospital or by a registered medical practitioner. New cases ('undiagnosed diabetes') were diagnosed according to the American Diabetes Association (American Diabetes Association, 1997) and World Health Organization criteria (World Health Organization, 1999). Metabolic syndrome was diagnosed based on International Diabetes Federation criteria (Alberti et al., 2006). Details of blood sample collection and biochemical analysis have been previously described (Katulanda et al., 2008). Seated blood pressure was recorded on two occasions after at least a 10-min rest using an Omron IA2 digital blood pressure monitor (Omron Healthcare, Asia-Pacific Region, Singapore).

2.3. Statistical analyses

All data were double-entered and cross checked for consistency. Data were analysed using SPSS version 14 (SPSS Inc., Chicago, IL, USA) and Stata/SE 10.0 (Stata Corporation, College Station, TX, USA) statistical software packages. Height is reported according to the year of birth, gender, household income, level of education and sector of residence. The significance of the differences between proportions (%) and means were tested using z-test and Student's t-test or ANOVA, respectively.

A multivariate analysis was performed in both males and females with ‘height’ as the dependent variable and year of birth (stratified in to birth decades), level of education, household income and sector of residence (Urban/Rural) as the independent variables (co-variates). For each independent variable with more than two categories, dummy variables were created. The first category was taken as the reference category for these variables (year of birth – ‘Before 1936’, level of education – ‘no formal education’, household income – ‘<LKR 6999/ <US$ 61.9’). In all statistical analyses P values <0.05 were considered significant.

3. Results

Out of the 5000 invited subjects, 4532 participated in the study (response rate 91%). This report is based on 4477 subjects excluding 55 subjects with incomplete data. In our sample 39.5% were males and 17.6% were from the urban population (21% of Sri Lankans are urban). The highest mean height (±SD) in males and females was observed in those born after 1977 (youngest age group). The mean height showed a significant negative correlation with year of birth in both males (p < 0.001, r = −0.258) and females (p < 0.001, r = −0.310).
There was no significant difference between mean heights of urban and rural males (Table 1). However, the rural females were significantly taller than the urban (p < 0.001). In both males and females a dip was observed in the height curve for the urban sector among those born in the 1957–1966 period (Fig. 1).

The regression model for males and females explained 10.8% ($R^2 = 0.108$) and 13.5% ($R^2 = 0.135$) of the variance in height, respectively. The analysis of variance revealed that the final models for males ($F_{16,1751} = 13.28$) and females ($F_{16,2692} = 26.25$) were significant (p < 0.001). In both males and females, the strongest predictor of height was year of birth, followed by level of education and household income, respectively (Table 2). A separate regression analysis using only one construct for each of the about co-variates was performed and the results are presented in Table 3.

Height of all adults showed a significant negative correlation with fasting blood glucose levels (p < 0.05, $r = -0.052$), 2h post-glucose blood glucose levels (p < 0.001, $r = -0.089$) and presence of diabetes (p < 0.001, $r = -0.069$). Similarly, there was a significant negative correlation between mean systolic blood pressure

Table 1
Mean height (cm) according to the gender, area of residence and year of birth.

<table>
<thead>
<tr>
<th>Residence</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean height (±SD) cm</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>n = 308 164.6 ± 7.2</td>
<td>n = 477 151.3 ± 7.2</td>
</tr>
<tr>
<td>Rural</td>
<td>n = 1460 163.4 ± 6.8</td>
<td>n = 2232 151.4 ± 6.2</td>
</tr>
<tr>
<td>Year of birth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before 1936</td>
<td>n = 149 159.0 ± 6.8</td>
<td>n = 185 146.0 ± 6.5</td>
</tr>
<tr>
<td>1937–1946</td>
<td>n = 212 161.6 ± 6.0</td>
<td>n = 324 149.2 ± 6.2</td>
</tr>
<tr>
<td>1947–1956</td>
<td>n = 344 163.4 ± 6.7</td>
<td>n = 548 150.8 ± 5.9</td>
</tr>
<tr>
<td>1957–1966</td>
<td>n = 418 163.9 ± 6.3</td>
<td>n = 672 151.5 ± 6.2</td>
</tr>
<tr>
<td>1967–1976</td>
<td>n = 333 165.1 ± 6.7</td>
<td>n = 553 152.8 ± 6.1</td>
</tr>
<tr>
<td>After 1977</td>
<td>n = 312 165.6 ± 7.1</td>
<td>n = 427 154.0 ± 5.9</td>
</tr>
<tr>
<td>Total</td>
<td>n = 1768 163.6 ± 6.9</td>
<td>n = 2709 151.4 ± 6.4</td>
</tr>
</tbody>
</table>

Fig. 1. Multiple regression analysis coefficients of height according to the year of birth and area of residence in (a) males and (b) females.
and height \(p < 0.05, r = -0.032\). However, this was not observed for the mean diastolic blood pressure. Height also demonstrated significant correlations with total cholesterol \(p < 0.001, r = -0.106\), HDL cholesterol \(p < 0.001, r = -0.142\), LDL cholesterol \(p < 0.001, r = -0.104\) and triglyceride \(p < 0.001, r = 0.064\) levels. Similar correlations were observed in both genders (Table 4).

The mean heights \(± SD\) of patients with metabolic syndrome and without metabolic syndrome were 154.8 ± 8.8 cm and 156.6 ± 8.9 cm respectively. Patients with metabolic syndrome were significantly shorter than those without metabolic syndrome \(p < 0.001\).

4. Discussion

In the present study we arranged age groups according to the year of birth to speculate on the secular trends of height in Sri Lankan adults. Accordingly, a distinct secular trend of increasing height was demonstrated in Sri Lankan adults. Like other phenotypic traits, height is determined by a combination of genetic and environmental factors.

Thus, the observed secular trends in height may be due to the improvement of nutritional and socio-economic factors. Data from food balance sheets indicate that the per capita calorie availability has increased in Sri Lanka, from 2250 kcal in 1989–1991 to 2390 kcal in 2001–2003 (Food and Agriculture Organization, 2004). Thus, it is likely that the improvements in socio-economic factors and the changes in food intake which occurred in the last decades in Sri Lanka might partly explain the increase in height observed in this study.

Sri Lanka is a developing country in the South-East Asian region. South Asians are among the shortest populations in the world. The mean height of Sri Lankan males and females were 163.6 ± 6.9 cm and 151.4 ± 6.4 cm, respectively. The observed height of Sri Lankan adults was comparable to published data from other regional countries (Table 5).

Table 2
Multiple regression analysis of height (cm) of Sri Lankan adults, 2005–2006.

<table>
<thead>
<tr>
<th>Year of birth</th>
<th>Male (β)-coefficient (Standard error)</th>
<th>Female (β)-coefficient (Standard error)</th>
<th>(p) value</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1936</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1937–1946</td>
<td>2.258 (0.700)</td>
<td>&lt;0.01</td>
<td>2.870 (0.557)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1947–1956</td>
<td>3.638 (0.652)</td>
<td>&lt;0.001</td>
<td>4.027 (0.522)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1957–1966</td>
<td>4.136 (0.635)</td>
<td>&lt;0.001</td>
<td>4.345 (0.517)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1967–1976</td>
<td>5.021 (0.664)</td>
<td>&lt;0.001</td>
<td>5.430 (0.536)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>After 1977</td>
<td>5.581 (0.677)</td>
<td>&lt;0.001</td>
<td>6.447 (0.562)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 3
Multiple regression analysis of height (cm) of Sri Lankan adults, with continuous independent variables.

<table>
<thead>
<tr>
<th>(β)-coefficient (Standard error)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>159.1</td>
<td>145.6</td>
</tr>
<tr>
<td>(R^2)</td>
<td>9.1%</td>
<td>12.3%</td>
</tr>
<tr>
<td>(F)</td>
<td>44.7</td>
<td>95.67</td>
</tr>
</tbody>
</table>

Table 4
Relationship between height and metabolic parameters.

<table>
<thead>
<tr>
<th>Metabolic parameter</th>
<th>Correlation coefficient (r)</th>
<th>All (p) value</th>
<th>Male (p) value</th>
<th>Female (p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting blood glucose(^1)</td>
<td>-0.052*</td>
<td>-0.068*</td>
<td>-0.052*</td>
<td></td>
</tr>
<tr>
<td>2 h post glucose blood glucose(^1)</td>
<td>-0.089*</td>
<td>-0.062*</td>
<td>-0.089*</td>
<td></td>
</tr>
<tr>
<td>Presence of diabetes</td>
<td>0.069*</td>
<td>0.105*</td>
<td>0.069*</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure(^1)</td>
<td>-0.032*</td>
<td>0.097*</td>
<td>0.123*</td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure(^1)</td>
<td>-0.028*</td>
<td>0.010*</td>
<td>0.029*</td>
<td></td>
</tr>
<tr>
<td>Total cholesterol(^1)</td>
<td>-0.106*</td>
<td>-0.117*</td>
<td>-0.103*</td>
<td></td>
</tr>
<tr>
<td>LDL cholesterol(^1)</td>
<td>-0.104*</td>
<td>-0.102*</td>
<td>-0.083*</td>
<td></td>
</tr>
<tr>
<td>HDL cholesterol(^1)</td>
<td>-0.142*</td>
<td>-0.083*</td>
<td>-0.018*</td>
<td></td>
</tr>
<tr>
<td>Triglycerides(^1)</td>
<td>0.064*</td>
<td>0.079*</td>
<td>0.097*</td>
<td></td>
</tr>
</tbody>
</table>

\(p < 0.001.\)

\(^1\) Mean.
The extent of sexual dimorphism in heights, defined here as the difference in mean heights divided by the average of mean heights, was 7.7%. Differential access to health care and nutrition could partially account for the observed gender dimorphism. However, in the separate regression analysis for males and female, the coefficient for any given year of birth is larger in magnitude for females than males. This means that the average height of females has increased over the years more than compared to that of males. This is also demonstrated by the reduction in the gender dimorphism from 8.3% in those born prior to 1936 to 7.2%, in those born after 1977. One probable reason for this phenomenon could be that females are gaining equal/ increased access to health care and nutrition as males during the recent years compared to the past in Sri Lanka.

A significant difference in height was not observed between urban and rural sector of residence in both males and females. This is in contrast to India (Viswanathan and Sharma, 2009). The current study considered the present area of residence of subjects rather than the area of origin. Some of the urban subjects would have been originally from or born in rural areas and rapid urbanization has resulted in mixing of the urban and rural population. These factors may have resulted in a reduced difference of anthropometric parameters between the urban and rural populations.

The dip in the height curve observed in the urban sector males and females born between 1957 and 1966 (who were in their pubertal age during the 1970s) could be due to the global economic recession seen during the 1970s (Pérez-Toro, 2000). Since most of the food production in Sri Lanka occur in the rural areas, these areas of the country may have been least affected due to the global economic recession. In fact, historical time series for average human height has been shown to exhibit short- and medium-term cycles that can be associated with business cycles (Sunder and Woitek, 2005; Komlos, 1998). The observed secular increase in height highlights the need for regular monitoring of height at population level. The increased height in current versus previous generations of adults may have important implications with regards to the assessment and interpretation of anthropometric data and other health related factors (blood pressure and cardiovascular disease risk) affected by height.

The level of education and household income were the other significant predictors of adult height apart from year of birth both in males and females. Taller people were better educated and had a higher level of income. This is in keeping with data from other populations (Silventoinen et al., 1999). The level of education attained by a Sri Lankan adult and per capita income has steadily increased during the last few decades (Central Bank of Sri Lanka, 2008). Level of education which is an indicator of intelligence is known to be associated with health (Gottfredson and Deary, 2004). There are several potential explanations for the positive relationship between education and health: (1) a better education is associated with higher wealth and hence such people are able to invest more on health; (2) education leads to a better health through promotion of healthy behaviour and (3) other factors such as genetic endowment and social background affecting health and education in a similar way. During early childhood both cognitive and physical functions develops together and are influenced by environmental factors. The children who do not reach their potential heights due to unsatisfactory environmental conditions do not attain their full cognitive potential. It is this lack of full cognitive development that accounts for lower levels of education, and lower earnings in adulthood. The level of education was a stronger predictor of final adult height than household income in both genders. However, the present study considered the household income at the time of study rather than economic conditions in childhood which could be a better indicator of adult height. This could partly explain the stronger relationship between height and level of education than income. However, previous studies considering childhood economic conditions than household income have also demonstrated similar associations as in the present study (Silventoinen et al., 1999).

Short stature was associated with higher levels of fasting blood glucose, 2 h post-glucose blood glucose, systolic blood pressure, total cholesterol, HDL cholesterol, LDL cholesterol. In addition, it was associated with the presence of diabetes and metabolic syndrome. Greater sitting height has been demonstrated to be associated with diabetes and dyslipidemia and integrating the influence of height had significantly reduced the misdiagnosis of metabolic syndrome. (Schooling et al., 2007; Shimajiri et al., 2008). However, the strength of the association in the present study was weak for most metabolic parameters except for total cholesterol levels. Exceptions to the relationship between height and cardiovascular risk have been reported that casts doubt on the significance of height on adverse cardiovascular disease outcomes (Goldburt and Tanne, 2002; Liao et al., 1996; Olatunbosun and Bella, 2000; Song et al., 2003; Sichieri et al., 2000; Velasquez-Melendez et al., 1999). Most of these reports describing height and ischaemic heart disease are from Western Europe and North America and are comparatively recent (i.e., within the last 60 years), coming many decades after the industrialization of the economies in those regions. In contrast, studies finding little or no relationship between height and ischaemic heart disease and diabetes or its risk factors predominantly come from underdeveloped countries, such as Brazil (Sichieri et al., 2000) and Nigeria (Olatunbosun and Bella, 2000) or recently developed economies, such as South Korea (Song et al., 2003). This could partly explain the weak relationship found between

<table>
<thead>
<tr>
<th>Country</th>
<th>Height (cm)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sri Lanka</td>
<td>163.6</td>
<td>151.4</td>
<td></td>
</tr>
<tr>
<td>Indiaa</td>
<td>161.2</td>
<td>152.1</td>
<td></td>
</tr>
<tr>
<td>Chinab</td>
<td>166.3</td>
<td>157.0</td>
<td></td>
</tr>
<tr>
<td>Malaysiac</td>
<td>164.7</td>
<td>153.3</td>
<td></td>
</tr>
<tr>
<td>Indonesiaa</td>
<td>158.0</td>
<td>147.0</td>
<td></td>
</tr>
</tbody>
</table>

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* a Deaton (2008).
  b Yang et al. (2005).
  c Lim et al. (2000).
metabolic parameters and height in a developing country like Sri Lanka.

This study has several limitations. Absence of data on pubertal age prevented us from analyzing the effect of changing pubertal age on the final adult height. The Northern and Eastern provinces of the country with a majority Tamil and Muslim population were excluded from the study due to the war that was present in these areas at the time of the study. Pocket stadiometers were used for the measurement of height considering ease of transport and use. Measurement errors were kept to a minimal by ensuring strict adherence to guidelines and regular training of data collectors.

Acknowledgements

The National Science Foundation of Sri Lanka was the primary source of funding for the study. The additional support provided from the Oxford Centre for Diabetes Endocrinology and Metabolism, UK and the NIHR Biomedical Research Centre Programme is gratefully acknowledged. We thank the Diabetes Association of Sri Lanka and the World Health Organization Office in Colombo for the support for lipid assays. The authors thank all individuals and institutions who helped and worked for the study.

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