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# Ethnic differences in anthropometry among adult Singaporean Chinese, Malays and Indians, and their effects on lung volumes

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When standing height (StndHt) cannot be assessed, arm span (AS) or sitting height (SitHt) has been used as surrogate variables for prediction of StndHt in adult caucasians and blacks. We examined (1) the relationship between StndHt, AS and SitHt among adult Chinese, Malays and Indians; and (2) whether anthropometry could explain the ethnic differences in lung volumes (as StndHt-adjusted lung volumes are known to differ significantly: Chinese > Malays > Indians).

We recruited 1250 consecutive outpatients aged 20–90 years. Prediction equations of StndHt (with AS, SitHt, weight, age as predictors) for each subgroup of race and sex were formulated with multiple linear regressions.

Equations with both AS and SitHt as predictors had the best goodness of fit (SEE = 2·37–2·85 cm, adjusted $R^2$ = 0·67–0·87), as compared to equations with either AS (SEE = 3·00–3·91 cm, adjusted $R^2$ = 0·58–0·80) or SitHt alone (SEE = 3·48–4·00 cm, adjusted $R^2$ = 0·45–0·76). GLM general factorial analyses found that age- and weight-adjusted SitHt-to-StndHt ratios differed significantly among Chinese (0·539), Malays (0·529) and Indians (0·518). This paralleled the ethnic differences in lung volumes.

The equations with both AS and SitHt as predictors provide the most accurate estimate of StndHt. Ethnic differences in upper body segment length may explain in part the lung volume differences.

**Key words:** standing height; sitting height; arm span; forced vital capacity; ethnic differences.

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## Introduction

Standing height (StndHt) is an essential variable in most of the regression equations for deriving predicted normal lung function values. However, in certain clinical circumstances, StndHt cannot be assessed directly. These include patients who are unable to stand erect because of severe debility or neuromuscular diseases, patients with axial skeleton or thoracic cage deformities, and patients who are handicapped by lower limb defects, such as amputees. In such cases, arm span (AS) (1–3) and sitting height (SitHt) (4,5) have separately been proposed as surrogate variables, and they generally provide relatively good correlation with StndHt.

In adults, the relationships between AS, SitHt and StndHt have been well established among Caucasians (1,2,4) and blacks (2,5). However, in adult Asians, there is a paucity of data. Other than a study among North Indian adults by Aggarwal *et al.* (3), there has been no other study performed in a homogeneous ethnic group among Asian adults. Due to the existence of anthropometric variability, however, specific prediction equations are needed for these ethnic groups individually (1). Moreover, the available prediction equations for StndHt utilize either AS or SitHt alone as predictors (1–4). There has been no previous report investigating whether the combination of both AS and SitHt as predictors can provide an even better estimate for StndHt.

Race is one of the important factors that account for lung function differences between individuals. Even after adjusting for age, sex and StndHt, inter-ethnic differences in lung volumes persist. Caucasians are known to have larger lung volumes than blacks (6–8). Hsi *et al.* showed that by using SitHt instead of StndHt as the predictor, inter-ethnic differences in forced vital capacity (FVC) and forced expiratory volume in 1 sec ($FEV_1$) across the three races of black, white and Mexican–American children could be markedly reduced (6). A possible explanation is that SitHt, being a measure of upper body segment length, provides a better measure of the thoracic cavity size and lung volumes than StndHt. A previous local study also shows that lung volumes differ significantly among adult Chinese, Malays and Indians, in descending order (9). It is not known if

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SitHt can explain the inter-ethnic differences in lung volumes amongst adult Asians, and between Asians and Caucasians.

Therefore, the goals of this study are: (1) to determine the relationship between StndHt with AS and SitHt among adult Chinese, Malays and Indians; and (2) to determine if ethnic differences in upper body segment length (or SitHt) could explain the established ethnic differences in lung volumes.

# Methods

## PATIENT RECRUITMENT

This was a cross-sectional study conducted in the respiratory specialist outpatient clinic of an urban hospital serving 1068 beds. The clinic serviced a wide range of general medical cases, with a predominance of respiratory cases. We recruited 1250 consecutive attendees to the clinic between November 1998 and January 1999. Verbal consent was obtained from the patients.

## EXCLUSION CRITERIA

The subjects were screened for the following exclusion criteria: (1) patients who were too frail to stand upright for body measurements; (2) patients with deformities affecting the axial skeleton or thoracic cage; (3) patients who had taken more than 2 weeks of systemic corticosteroids in 1 year; (4) patients with deformities of the upper limbs or lower limbs; and (5) patients who were not residents of Singapore. The last exclusion criteria aimed to reduce any possible confounding environmental factors that might have resulted in varying differential growth.

## MEASUREMENTS

The measurements were performed by four trained respiratory function laboratory technicians. StndHt was measured with the patient standing erect, heels together, and with the back of the head, shoulders, buttocks and heels against the wall. The patient looked forward with the head held in Frankfurt plane, i.e. the standard orientation with the lowest point of the bony orbit and the highest point on the margin of the cutaneous external auditory meatus in the same horizontal plane (1,7,10–13). Measurement was then taken using a fixed centimetre tape measure vertically mounted on the wall.

SitHt was measured using the same method as for StndHt, except with the patient sitting on a firm, wooden chair of known height. The SitHt was measured as the distance from the highest point of the head to the inferior surface of the buttocks, i.e. the seat of the chair (7,10–13). AS was taken with the patient standing upright and with the back against the wall. It was measured as the distance from the outermost tip of the middle finger of one hand to that of the other, with the arms stretched out and abducted to 90°, and palms facing forward (1,10,13). The lengths were measured to the nearest 0·1 cm. Leg length was calculated as StndHt − SitHt (7,10,13).

Body weight (Wt) was measured to the nearest 0·5 kg, with the patient wearing only light clothing and without shoes. Patient's diagnoses, race, sex and date of birth were also recorded. Age was recorded as years at the last birthday.

## RELIABILITY OF MEASUREMENTS

Both intra-rater and inter-rater reliability of body length measurements were performed during the study. We recruited 21 healthy volunteers from the hospital staff and measurements were taken by the four technicians involved in the study. For intra-rater reliability, the StndHt, SitHt and AS of each subject were measured twice by the same technician on two separate occasions. For inter-rater reliability, each subject was measured by all four different technicians separately. The readings were analysed pairwise, and the difference between each pair of readings was computed. The mean and standard deviation (SD) of the differences, and the limits of agreement were computed as outlined by Bland and Altman (14). Furthermore, the inter-rater reliability was also assessed by the intra-class correlation coefficient, which reflected both the degree of correspondence and the degree of agreement among the different readings (15).

## STATISTICAL ANALYSES

Age, Wt, body length and ratio values were expressed as mean and SD. One-way ANOVA with post-hoc Bonferroni's test was performed for the comparison of age and Wt between the different ethnic groups. Multiple linear regression analysis was used to formulate prediction equations with StndHt as the dependent variable and AS, SitHt, Wt, and age as the predictors. Individual prediction equations were formulated for each subgroup of race and sex. The violations of the assumptions of heteroscedascity, multicollinearity and normality were checked by runs test, variance inflators and Kolmogorov–Smirnov tests.

GLM general factorial analysis was used to calculate the age- and body weight adjusted body lengths and ratios, and post-hoc Bonferroni's test with multiple comparisons between the three ethnic groups were performed. These statistical analyses were performed with SPSS for Windows Release 8.0.

## UPPER BODY SEGMENT RATIO AND LUNG VOLUMES: INDIRECT COMPARISON BETWEEN ASIANS AND CAUCASIANS

The upper body segment ratio was computed as the SitHt:StndHt ratio. Indirect comparison of the SitHt:StndHt ratio and FVC between Asians and Caucasians was performed. The data for the FVC of Chinese, Malays and Indians was obtained from a previously published local study from the same lung function laboratory (9). The SitHt:StndHt ratio (4,7,16) and FVC (17–23) of Caucasians were selected from previous large studies with 100 subjects and above. The mean SitHt:StndHt ratio and mean FVC were computed as weighted means based on the number of subjects in each study.

## Results

### DEMOGRAPHY

The preponderance of Chinese recruited in this sample (Table 1) closely reflected the 1998 demographic pattern in Singapore (Chinese 77·0%, Malays 14·1% and Indians 7·6%) (24). As shown in Table 2, Malay women were significantly younger than Chinese women ($P = 0{\cdot}017$); Chinese men were significantly lighter than Indian men ($P < 0{\cdot}01$); and Chinese women were significantly lighter than both Indian ($P < 0{\cdot}01$) and Malay women ($P < 0{\cdot}01$).

### RELIABILITY OF MEASUREMENTS

For intra-rater reliability, the limits of agreement of StndHt, SitHt and AS measurements all fell within the range of $-0{\cdot}86$ cm and $+0{\cdot}78$ cm (Table 3); the corresponding limits of agreement of inter-rater measurements all fell within the range of $-0{\cdot}92$ cm to $+1{\cdot}02$ cm. This magnitude of errors in measurements was deemed to be clinically not significant when they were translated into the calculation of the various ventilatory function tests. Moreover, the inter-rater reliability of all these three body measurements also showed an excellent single measure intra-class correlation coefficient of 0·997 or more.

### PREDICTION EQUATIONS FOR STANDING HEIGHT

Individual prediction equations for each subgroup of race and sex are as shown [Table 4(a–c)]. The assumptions of

TABLE 1. Demography — the number of subjects for each age group

| | | Age groups (years) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 20–29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | ≥80 | Total |
| Chinese | Male | 95 | 61 | 108 | 107 | 122 | 83 | 20 | 596 |
| | Female | 34 | 34 | 91 | 87 | 80 | 42 | 12 | 380 |
| | Both sexes | 129 | 95 | 199 | 194 | 202 | 125 | 32 | 976 (78·1%)* |
| Malay | Male | 8 | 12 | 11 | 16 | 15 | 9 | 0 | 71 |
| | Female | 4 | 11 | 18 | 10 | 4 | 4 | 0 | 51 |
| | Both sexes | 12 | 23 | 29 | 26 | 19 | 13 | 0 | 122 (9·8%)* |
| Indian | Male | 19 | 6 | 15 | 10 | 18 | 9 | 0 | 77 |
| | Female | 4 | 11 | 23 | 14 | 19 | 3 | 1 | 75 |
| | Both sexes | 23 | 17 | 38 | 24 | 37 | 12 | 1 | 152 (12·2%)* |
| Total | | | | | | | | | 1250 (100%) |

*Figures in brackets are percentages of patients in the total population.

TABLE 2. Age and body weight

| | | Chinese | Malay | Indian | All races |
|---|---|---|---|---|---|
| Male | Age | | | | |
| | Mean ± 1 SD | 51·5 ± 17·6 | 50·7 ± 16·5 | 48·2 ± 18·0 | 51·1 ± 17·5 |
| | Range | 20–88 | 20–79 | 20–78 | 20–88 |
| | Weight | | | | |
| | Mean ± 1 SD | 63·8 ± 13·9 | 67·7 ± 19·7 | 69·4 ± 14·8 | 64·7 ± 14·7 |
| Female | Age | | | | |
| | Mean ± 1 SD | 52·9 ± 15·1 | 46·8 ± 13·0 | 50·4 ± 12·8 | 51·9 ± 14·7 |
| | Range | 20–90 | 21–79 | 23–86 | 20–90 |
| | Weight | | | | |
| | Mean ± 1 SD | 54·1 ± 11·0 | 60·6 ± 12·5 | 64·5 ± 14·0 | 56·3 ± 12·2 |

Age expressed in years and weight in kg.

TABLE 3. Results for reliability tests of anthropometric measurements

| | | Difference | | Limits of agreement |
|---|---|---|---|---|
| | | Mean | SD | (Mean ± 2 SD) |
| Intra-rater measurement (cm) | Standing height | 0·05 | 0·35 | −0·66 to +0·75 |
| | Sitting height | 0·03 | 0·36 | −0·69 to +0·76 |
| | Arm span | −0·04 | 0·41 | −0·86 to +0·78 |
| Inter-rater measurement (cm) | Standing height | 0·02 | 0·35 | −0·68 to +0·71 |
| | Sitting height | 0·01 | 0·42 | −0·83 to +0·85 |
| | Arm span | 0·05 | 0·48 | −0·92 to +1·02 |

heteroscedascity, multi-collinearity and normality were not violated. The tables show three different sets of equations with: (a) both AS and SitHt included as predictors; (b) AS alone included as predictors; and (c) SitHt alone included as predictors. With the exception of three, all the equations showed a good adjusted $R^2$ of 0·6 and above.

We compared the three eqns (1), (7) and (13). These were all prediction equations for the Chinese men, but differed from one another by whether the predictors, AS and SitHt, were used singly or in combination. Comparison revealed that the standard error of estimate (SEE) was smallest in eqn (1), followed by eqns (7) and (13) in an ascending order, while the adjusted $R^2$ varied in the reverse order. This showed that the regression model of eqn (1) had the best goodness of fit. Similar analyses were performed for each of the remaining subgroups of race and sex in Table 4(a–c) and similar results were obtained.

Therefore, the prediction equations which included both AS and SitHt had the best goodness of fit and provided the best power of estimate of StndHt, as compared to equations with either AS or SitHt alone. Between the latter two, AS also seemed to be better than SitHt, with the only exception of Indian men in which the converse was true.

### BODY SEGMENT LENGTHS: DIRECT COMPARISON BETWEEN CHINESE, MALAYS AND INDIANS

Comparison of the various standardized body lengths and ratios [Table 5(a, b)] showed that Chinese generally had the shortest upper and lower limbs and longest trunk, in contrast to the Indians who had the longest limbs but the shortest trunk; the Malays were intermediate.

### UPPER BODY SEGMENT RATIO AND FVC: AN INDIRECT COMPARISON BETWEEN CHINESE, MALAYS AND INDIANS

With the data of a previously published local study (9), the FVC values of the Chinese, Malays and Indians were standardized based on an age of 45 years and a StndHt of 175 cm for comparisons (Table 6). Both the standardized FVC values and the SitHt:StndHt ratio showed a similar trend in their inter-ethnic variations. In other words, at a given StndHt, as the SitHt increased the FVC also increased correspondingly, and vice versa. A similar trend was observed among females. This implied that the ethnic differences in lung volumes might be explained at least partially by the variations in SitHt or upper body segment length among adult Chinese, Malays and Indians.

### UPPER BODY SEGMENT RATIO AND FVC: AN INDIRECT COMPARISON BETWEEN ASIANS AND CAUCASIANS

The mean SitHt:StndHt ratio (4,7,16) and the mean StndHt-adjusted FVC (17–23) of the Caucasians (Table 6) were computed from previously published studies. For the ease of comparison, we compared the results between that of Chinese and Caucasian men. A contradictory result was obtained. Although the Caucasians had a larger FVC, their upper body segment ratio was much smaller than that of the Chinese.

## Discussion

### PREDICTION EQUATIONS FOR STANDING HEIGHT

In this study, we have formulated the prediction equations for StndHt using AS and/or SitHt as predictors for adult Chinese, Malays and Indians, which will be clinically useful among these ethnic groups.

Furthermore, the results of our study reveal that the equations which include both AS and SitHt as predictors provide the most accurate estimate of StndHt, while equations with only AS or SitHt alone have a poorer fit. To the best of our knowledge, this relationship has never been examined by any other study previously. All available studies of StndHt estimation used either AS (1–3,13) or SitHt (4,5,13) as predictors separately. Therefore, whenever possible, prediction equations with both AS and SitHt

TABLE 4a. Prediction equations of standing height with both arm span and sitting height

| No. | | | Regression coefficients | | | | | Adjusted $R^2$ | SEE |
|---|---|---|---|---|---|---|---|---|---|
| | | | Constants | Arm span | Sitting height | Weight | Age | | |
| 1 | Chinese | Male | +5·181 | +0·511* | +0·859* | −0·0220* | +0·00085 | 0·86 | 2·47 |
| 2 | | Female | +15·507 | +0·488* | +0·767* | +0·00419 | +0·00589 | 0·82 | 2·37 |
| 3 | Malay | Male | +17·073 | +0·513* | +0·697* | +0·0184 | +0·00352 | 0·86 | 2·61 |
| 4 | | Female | +42·576 | +0·433* | +0·528* | −0·00296 | +0·0226 | 0·67 | 2·85 |
| 5 | Indian | Male | +0·745 | +0·485* | +1·025* | −0·0627* | −0·0274 | 0·87 | 2·81 |
| 6 | | Female | +24·813 | +0·559* | +0·554* | −0·0239 | −0·0306 | 0·80 | 2·42 |

TABLE 4b. Prediction equations of standing height with arm span alone

| No. | | | Regression coefficients | | | | Adjusted $R^2$ | SEE |
|---|---|---|---|---|---|---|---|---|
| | | | Constants | Arm span | Weight | Age | | |
| 7 | Chinese | Male | +52·877 | +0·673* | +0·0443* | −0·0355* | 0·73 | 3·41 |
| 8 | | Female | +53·711 | +0·660* | +0·0601* | −0·0658* | 0·70 | 3·06 |
| 9 | Malay | Male | +53·907 | +0·656* | +0·0654* | −0·0497† | 0·80 | 3·19 |
| 10 | | Female | +64·640 | +0·574* | +0·0214 | −0·0230 | 0·58 | 3·22 |
| 11 | Indian | Male | +37·414 | +0·754* | +0·0279 | −0·0255 | 0·75 | 3·91 |
| 12 | | Female | +51·804 | +0·673* | +0·0150 | −0·0811* | 0·69 | 3·00 |

TABLE 4c. Prediction equations of standing height with sitting height alone

| No. | | | Regression coefficients | | | | Adjusted $R^2$ | SEE |
|---|---|---|---|---|---|---|---|---|
| | | | Constants | Sitting height | Weight | Age | | |
| 13 | Chinese | Male | +46·686 | +1·347* | +0·00482 | −0·0248* | 0·63 | 4·00 |
| 14 | | Female | +48·492 | +1·233* | +0·0370* | +0·0315* | 0·61 | 3·48 |
| 15 | Malay | Male | +62·120 | +1·157* | +0·0560† | −0·0286 | 0·70 | 3·85 |
| 16 | | Female | +80·109 | +0·938* | −0·0563 | +0·00415 | 0·45 | 3·72 |
| 17 | Indian | Male | +42·167 | +1·519* | −0·0199 | −0·109* | 0·76 | 3·79 |
| 18 | | Female | +79·721 | +0·902* | +0·0287 | −0·00816 | 0·45 | 3·97 |

The regression model used was $Y = B_0 + B_1 \times (\text{arm span}) + B_2 \times (\text{sitting height}) + B_3 \times (\text{weight}) + B_4 \times (\text{age})$, where $Y$ = standing height; $B_0$ = constant; $B_1$, $B_2$, $B_3$ and $B_4$ = regression coefficients for arm span, sitting height, weight and age, respectively.

$^*P<0·05$; $^†P<0·1$. Standing height, sitting height and arm span are in cm, weight is in kg, and age is in years.

should be used for the prediction of StndHt as they provide the most accurate estimate.

## ANTHROPOMETRY AND LUNG VOLUMES

Our study has also shown that the upper body segment lengths differ significantly among adult Chinese, Malays and Indians, in descending order. This variation conforms to the pattern of inter-ethnic differences in StndHt-adjusted FVC, as shown in a previous local study (9). We found that for a given StndHt, the longer upper body segment length in Chinese is associated with a larger FVC, with the converse being true for Indians, and the Malays being intermediate. This, therefore, suggests that anthropometric differences in the upper body segment length may account, at least in part, for the ethnic differences in lung volumes.

Although this pattern of variation in upper body segment length conforms very well to the FVC differences among the Chinese, Malays and Indians, comparison to

TABLE 5a. Crude and age-adjusted and, weight-adjusted* body segment lengths and ratios for males

| | Male | | | P-values | | |
|---|---|---|---|---|---|---|
| | Chinese | Malay | Indian | Chinese vs. Malay | Chinese vs. Indian | Malay vs. Indian |
| Mean standing height ± 1 SD | 166·7 ± 6·6 | 166·2 ± 7·0 | 168·0 ± 7·8 | | | |
| | (166·9) | (165·7) | (166·9) | NS | NS | NS |
| Mean sitting height ± 1 SD | 89·8 ± 3·7 | 88·0 ± 4·2 | 87·2 ± 4·0 | | | |
| | (89·9) | (87·6) | (86·5) | < 0·0005 | < 0·0005 | †NS (0·072) |
| Sitting height/standing height ratio ± 1 SD | 0·539 ± 0·014 | 0·529 ± 0·014 | 0·519 ± 0·013 | | | |
| | (0·539) | (0·529) | (0·518) | < 0·0005 | < 0·0005 | < 0·0005 |
| Mean arm span ± 1 SD | 167·7 ± 7·6 | 168·3 ± 7·7 | 172·2 ± 8·4 | | | |
| | (167·9) | (167·8) | (171·0) | NS | < 0·0005 | 0·01 |
| Arm span/standing height ratio ± 1 SD | 1·006 ± 0·024 | 1·013 ± 0·022 | 1·025 ± 0·025 | | | |
| | (1·006) | (1·013) | (1·025) | †NS (0·072) | < 0·0005 | 0·008 |
| Mean leg length ± 1 SD | 76·9 ± 4·3 | 78·2 ± 4·2 | 80·8 ± 4·9 | | | |
| | (77·0) | (78·1) | (80·4) | †NS (0·095) | < 0·0005 | 0·002 |

TABLE 5b. Crude and age- adjusted and weight-adjusted* body segment lengths and ratios for females

| | Female | | | P-values | | |
|---|---|---|---|---|---|---|
| | Chinese | Malay | Indian | Chinese vs. Malay | Chinese vs. Indian | Malay vs. Indian |
| Mean standing height ± 1 SD | 154·9 ± 5·6 | 153·3 ± 5·0 | 154·0 ± 5·4 | | | |
| | (155·3) | (152·2) | (152·7) | < 0·0005 | < 0·0005 | NS |
| Mean sitting height ± 1 SD | 83·3 ± 3·6 | 81·5 ± 3·8 | 80·8 ± 3·9 | | | |
| | (83·7) | (80·6) | (79·8) | < 0·0005 | < 0·0005 | NS |
| Sitting height/standing height ratio ± 1 SD | 0·538 ± 0·014 | 0·532 ± 0·018 | 0·524 ± 0·018 | | | |
| | (0·539) | (0·529) | (0·523) | < 0·0005 | < 0·0005 | 0·035 |
| Mean arm span ± 1 SD | 153·6 ± 6·2 | 154·2 ± 6·7 | 156·5 ± 6·3 | | | |
| | (153·9) | (153·3) | (155·2) | NS | NS | NS |
| Arm span/standing height ratio ± 1 SD | 0·992 ± 0·024 | 1·006 ± 0·028 | 1·016 ± 0·024 | | | |
| | (0·991) | (1·007) | (1·016) | < 0·0005 | < 0·0005 | NS |
| Mean leg length ± 1 SD | 71·6 ± 3·6 | 71·8 ± 3·7 | 73·3 ± 3·9 | | | |
| | (71·6) | (71·7) | (72·9) | NS | 0·02 | NS |

Standing height, sitting height, arm span and leg length are in cm.
*Age- and body weight-adjusted values and shown in brackets.
†Statistically significant at 10% level.
NS denotes statistically not significant at 5% level.

Caucasians shows a contradictory result. Despite their smaller upper body segment ratio, the Caucasians have a larger FVC, as compared to the Chinese and Malays. As SitHt is a measurement of only the vertical dimension of the trunk, we believe that the larger horizontal (or transverse) dimensions may contribute significantly to larger lung volumes in Caucasians.

We acknowledge that there are limitations to our study as the observations made are based on indirect comparisons. Technical variations are typical confounding factors that often make indirect comparisons difficult. These factors include differing measuring techniques, equipments, technicians and measuring environments. Different studies would also imply different geographic locations,

TABLE 6. Comparison of upper body segment length and FVC between ethnic groups (males)

| | Sitting height/standing height ratio | FVC* |
|---|---|---|
| Chinese | 0·539 | 4·10 |
| Malay | 0·529 | 3·83 |
| Indian | 0·519 | 3·45 |
| Caucasian† | 0·523‡ | 4·74§ |

*FVC values were standardized at the age 45 years and standing height 175 cm for comparison between ethnic groups.
†Mean sitting height-standing height ratio and mean FVC for Caucasians were computed as weighted averages according to the sample size of each study.
‡Refer to references 4, 7 and 16.
§Refer to references 17–23.

environmental factors and socio-economic circumstances, which may influence the differential growth rates. These variations are difficult, if not impossible, to control. Indirect comparison of studies performed at different time periods would also incur time as a confounding factor. 'Historical changes' in anthropometric measurements and lung functions with the progression of time may alter the characteristics of the studied populations. Comparison of studies done 20–30 years apart on the same population showed changes in body lengths, as well as body proportions (13,25).

Nonetheless, our study has made interesting observations on the relationship between frame size and lung volumes among different ethnic groups. Further studies that can provide direct comparison between Caucasians and Asians are required to confirm the issue.

## Conclusions

We conclude that: (1) both AS and SitHt accurately estimate StndHt among adult Chinese, Malays and Indians; (2) prediction equations which include both AS and SitHt as predictors provide the best estimate of StndHt, compared to equations with only AS or SitHt alone; and (3) variations in upper body segment length may account, at least partially, for the inter-ethnic differences in lung volumes among these Asians. However, inter-ethnic variations in upper body segment length in the vertical axis do not explain the differences in lung volumes between Asians and Caucasians.

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