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ARTICLE

Age changes in some linear measurements and secular trend in height in adult Indian women

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ABSTRACT Decline in linear body dimensions with age has been reported in studies throughout the world. There is sufficient evidence that a portion of the changes in stature in a cross-sectional study may be due to secular trend rather than ageing. In the present study, age changes in linear measurements were studied and an attempt made to partition the age associated decline in stature from that of secular trend in height in younger generation. Data comprised of 126 Maratha women patients living in Government Mental Hospital in Pune, India. Their age ranged from 30 to 70 years. Using stature and sitting height, sub-ischial height was derived for each subject which was used as an indirect measurement to approximate the secular trend in height gain in younger generation. Iliac height- a direct measurement was used to quantify the increase in height in younger cohorts. Analysis showed that almost 71 percent (2.55cms) of statural difference between youngest and oldest age group could be attributed to ageing effect, and remaining 29 percent (1.05cms) to secular trend in those born later in time. The timing of reduction in height appears to be in the fifth decade accelerating in subsequent decades.
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KEY WORDS

ageing
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The trend of a reduction in longitudinal skeletal dimensions with age has been reported by biological anthropologists from time to time in different populations around the world (Rossman 1977; Borkan 1982). Environmental conditions influencing growth and development also influence differential survivorship, secular trends and cohort associated effects which make it difficult to describe biological ageing adequately from cross- sectional data. It is because observations due to age changes can be distorted by the differences in maximum stature attained by different generations. Because of non-availability of fully longitudinal studies of ageing in developing countries, we yet need to rely on cross-sectional data for estimation of age changes; and their health implications in ripe old age.

Estimate of the ageing changes and secular effects in stature can be obtained if measurements are made of stature and of dimensions that do not change with ageing. Some investigators using long bones as a reference have approached this problem as long bones are highly correlated with stature and influenced by secular factors, but not by the ageing process. More than half a century back it was reported by Trotter and Glasser (1951) that if there is a significant trend with increasing age in sample statures after the change due to differences in long bone lengths has been removed or held constant statistically, this trend can be considered to be due to ageing. Later similar such studies were carried out which assessed the age associated statural loss and secular change separately (Hertzog et al. 1969; Himes and Mueller 1977; Relethford and Lees 1981).

A review of literature shows a good number of references about research on age changes mostly published between the 1950's and the 1980's (Trotter and Glasser 1951; Miall et al. 1967; Dequeker et al. 1969; Hertzog et al. 1969; Himes and Mueller 1977; Parizkova and Elselt 1980; Roche et al. 1981; Beall 1982; Malina et al. 1982; Borkan et al. 1983; Cline et al. 1989). Since then only a few studies of such topic (Galloway et al. 1990; Chandler and Bock 1991) could be found.

Present study was undertaken to assess the age changes in linear measurements in adult Indian women, and an attempt made to partition the age associated decline in stature from that of secular trend in height (if any) in the younger cohorts.

Material and Methods

Data were collected from women patients living in the Government Regional Mental Hospital located at Yerawada in Pune district of Maharashtra in India for examining the normal anthropometric changes with advancing age in them. Out of the total data collected on 266 women, only women belonging to the largest endogamous group (Maratha) numbering 126 were considered for the present study. Their age ranged from 30 years to 70 years and most were living in the hospital for more than 15 years, their diet and living condi-

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Table 1. Means of linear measurements.

Age group Meeasurement	30 - 39 Yrs. (N= 24) mean S.D.	40 - 49 Yrs. (N=45) mean S.D	50 - 59 Yrs. (N=31) mean S.D.	60 - 69 Yrs. (N=26) mean S.D.
Height (cms)	151.64±5.30	151.53±5.96	151.01±5.43	148.04±7.54
Sitting height	80.79±5.01	80.25±7.80	81.56±5.15	78.24±7.59
Sub-ischial Height	70.97±5.45	72.16±6.50	69.36±5.31	69.78±6.77
Iliac height	87.52±8.74	86.09±9.07	88.58±8.04	86.08±9.87

Table 2. Total change, per cent change and rate of change.

Measurement (Age group 30-70 yrs)	Total change	Percent Change	Rate of change/ decade
Stature	-3.6 cm	2.37	1.2 cm
Sitting height	-2.55 cm	3.15	-0.85 cm
Sub-ischial length	-1.19 cm	2.80	-0.39 cm
Iliac height	-1.44 cm	1.65	-0.48 cm

Table 3. Correlation coefficient of linear measurements.

	Age	Height	Sitting height	Sub-ischial height	Iliac height
Age	1.000	-.191*	-.092	-.153	.008
Height	-.191*	1.000	.618**	.321**	.427*
Sitting height	-.092	.618**	1.000	-.470**	.356*
Sub-ischial height	-.153	.321**	-.470**	1.000	.015
Iliac height	-.008	.427**	.356**	.015	1.000

*Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 4. Regression equation of linear measurements.

Parameters	d.f.	F	Sig f	b0	b1
Height	98	5.06	0.027	156.391	-0.1212
Sitting height	98	.41	0.523	82.1636	-0.0386
Sub-ischial height	98	2.78	0.098	74.9106	-0.0894
Iliac height	105	0.23	0.634	88.859	-0.0348

tions being uniform. Necessary permission was obtained from the Ministry of Health of Maharashtra State for data collection and an undertaking given to maintain the privacy of the same. In the absence of any formal ethical committee at the time of data collection, in consultation with the Superintendent of the hospital, data were collected from only cooperative patients who readily agreed to participate in the study. For this purpose help was sought from the medical social welfare officer of the hospital.

General assumption of the study was that after completion of human body growth such measurements (considered in the study - stature, sitting height and iliac height) of an adult remain largely unaffected by mental health status. Total data size and number of probands in each age group was a limitation as it is a study where the sample consists of physical disability- free subjects (for accurate anthropometric measurements) from one of the largest mental hospitals in India. Anthropologically speaking, for such a study subjects selected needed to belong to the same ethnic/ endogamous caste group. Plenty of subjects had to be excluded (N=140), for one reason or another mainly because of caste differences, physical disability and patients not agreeing or inability to participate due to poor mental state.

Out of a total of 37 measurements performed to study the normal changes in human body with advancing age, only measurements needed for estimation of changes in linear measurements such as stature, sitting height and iliac height were considered for the present study. Anthropometric measurements were performed following standard techniques as described by Weiner and Lourie (1969). Sub-ischial height was derived (sub-ischial height = stature - sitting height) and used as an indirect measure to approximate the secular trend in height gain in younger generation. Iliac height, a direct measurement was used to quantify the possible increase in height in younger cohorts. The age of 30-39 years was taken as the period of maximum attainment of stature which constituted the control. Statistical Package for Social Sciences (SPSS) was used for analysis which included the calculation of coefficient of correlation and regression.

Analysis and Results

Means and standard deviations of stature, sitting height, and iliac height are given age- decade wise in Table 1.

Stature

Differences in means of stature between younger and older groups of women were substantial especially in the 60 years and above age- group (Table 1). A statistically significant decline in stature with advancing age highlights a significant negative correlation of stature with age ($r = -0.191^*$; $P = 0.05$). Since the coefficient of correlation between the stature

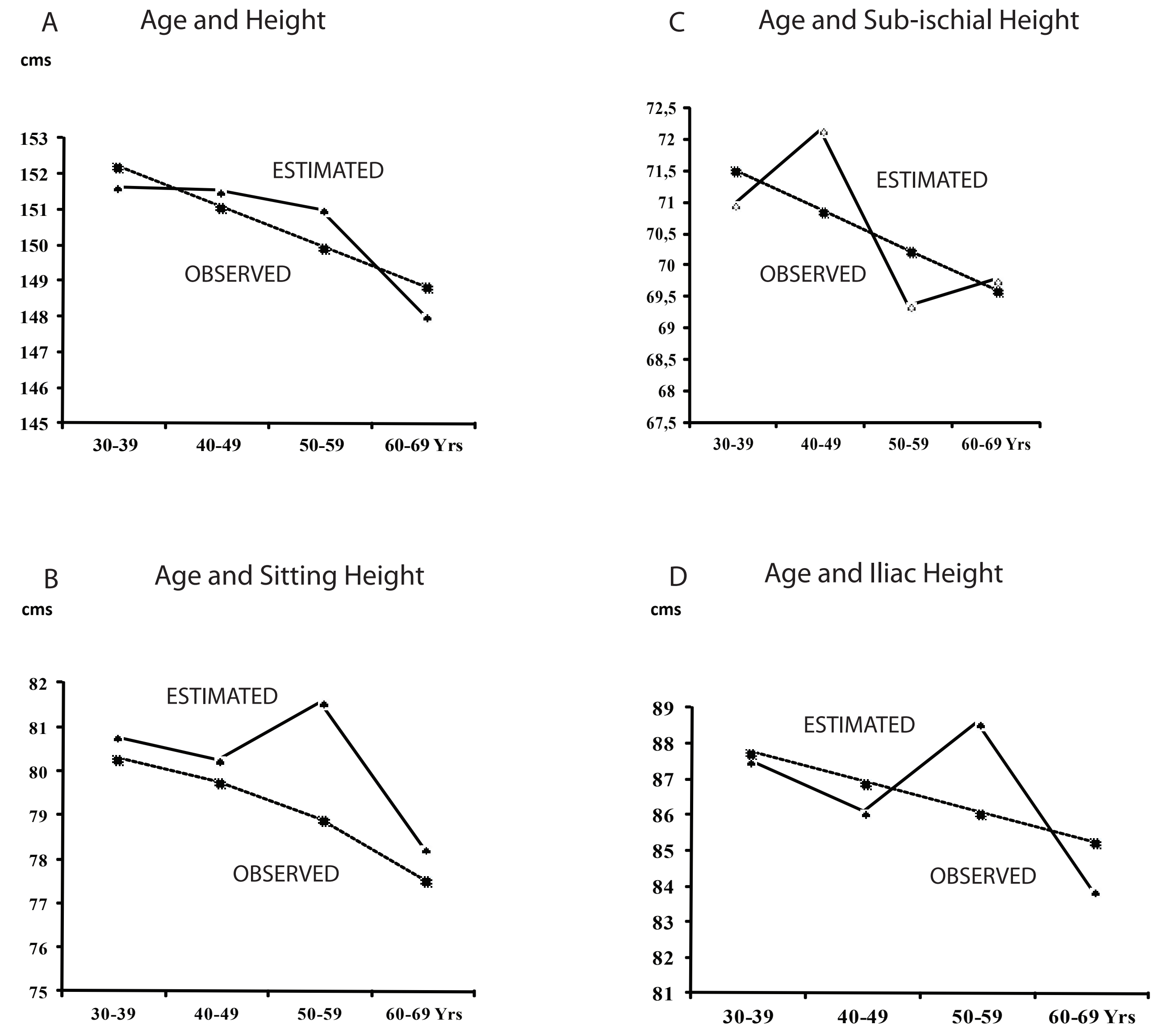

Figure 1. Relation between age and some linear measurements.

and age was significant (Table 3), regression equation for stature on age was computed (Table 4; Figs. 1A, 2A) and the regression values were also significant at 5% level with p-value of 0.04 by F-test (b0 = 156.50 and b1 = -0.118).

Sitting Height

Just like stature, a decreasing trend in sitting height also was marked in women under study. It became more pronounced in post sixties age group. Coefficient of correlation of sitting height and age was negative (r = -0.0919) and regression (b1) equation showed a decline in sitting height with advancing age (Table 4; Figs. 1B, 2 B).

Sub-Ischial height (Height - Sitting Height)

Sub-ischial height showed the maximum values in the fifth decade (40-49 yrs.) reflecting upon the possible secular increase in height in the younger women under study. Coefficient of correlation (r = -0.153; P = 0.146) and regression equation of sub-ischial height and age were negative though statistically non-significant (Tables 3 and 4). This showed that as age increased sub-ischial height decreased (Fig. 1C). In other words, sub-ischial height in the younger cohort (30-39 yrs) was more than the older group indicating the possibility of a secular increase in long bones in the younger group. Older subjects, it seems, never attained this height. Total difference

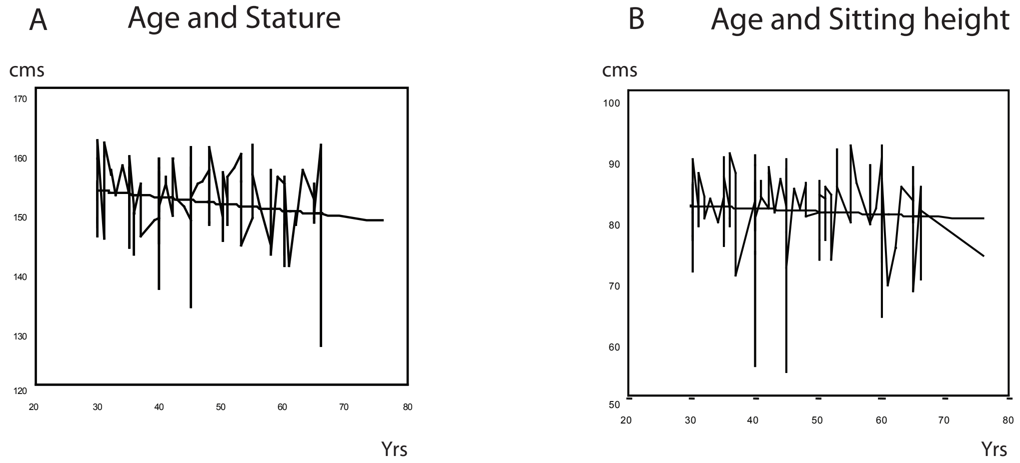

Figure 2. Relation and regression line between Age and some linear measurements. A: Age and Stature. B: Age and Sitting height.

in means of sub- ischial height between the youngest and the oldest group was 1.19 cms and percent change estimated was 2.8 per cent (Table 2). Rate of secular increase in height calculated was 0.39 cms per decade for the changes in three decade's time period (calculated from the intervening period between four decades under study).

Iliac height

Total difference in iliac height in youngest and oldest age group was 1.44 cms and percent change was 1.65 per cent of this measurement of youngest age group. The rate of change calculated for iliac height was 0.48 cms per decade, for the three decadal differences between the four age groups under study. Correlation coefficient was statistically non-significant (Table 3). The lower values for this measurement in older group indicated not that older subjects had lost iliac height- a measure of leg length but that the younger cohort was taller due to the probability of secular gain in height (which happens mainly in leg length) (Table 2).

Iliac height, comprising of mainly long bones of lower extremities, is the direct measurement to assess any gain in height due to secular trend, which, in the present study is actually showing relatively more gain (1.44 cms) than calculated by indirect results (1.19 cms.) arrived at by using sub- ischial height (Table 2).

Discussion

In accordance with the trend reported from around the world, present study also proposes a definite declining trend in most of the measures of length between the youngest and oldest group of women. The negative correlation of most of the linear dimensions with advancing age typically reflects the nature of changes that probably take place in human body in post post-adulthood phase. It has been widely acknowledged by skeletal biologists that a perceptible decline in stature takes place after maturity. This trend of a reduction in longitudinal skeletal dimensions with age can be substantiated by similar findings from various cross-sectional and longitudinal investigations in different populations of both men and women around the world (Eiben 1960; Miall et al. 1967; Parizkova and Elselt 1968; Dequeker et al. 1969; Hertzog et al. 1969; Harvey 1974; Roche et al. 1981; Beall 1982; Malina et al. 1982; Borkan et al. 1983; Galloway et al. 1990; Kirchengast 1994). Barring a few (Bagga 1998; Bagga and Sakurkar 2013; Hussain, unpublished) not many studies focusing exclusively on age changes in Indian populations are reported (Bagga 2010). Changes of similar nature were reported in most of these studies. A few attempts made earlier in India took into consideration 60 years and over group as one last age group (Madhavan and associates 1964; Sharma et al. 1975; Sidhu et al. 1975; Singh 1978; Banerji and Sen 1984) which does not serve the purpose as such age changes are the fastest in post-sixties.

Reviewing several cross-sectional studies of adults, Borkan and associates (1982) found that there exist statural differences of approximately 7-10 cm between the ages of 20 years to 70 years. The calculated mean linear decline in stature of Maratha females understudy was 3.6 cms. In an earlier Indian cross-sectional study on adult Maratha (sub-group Kunbi) women between 30-70 years showed an almost similar decline of 3.7cms (Hussain, unpublished). These values do not differ much from those reported previously from other populations around the world. Woodruff-Pak (1988) commented that decline in height with age in women between ages 25 years to 75 years may total to as much as two inches. However, several cross-sectional studies report a decline exceeding it. For example, the cross- sectional difference in women between 25 years to 70 years was found to be 7.2 cm and 6 cm in two separate groups of Welsh women (Miall et al. 1967); 8.08 cm in women between the age of 30 years to 94 years (Dequeker et al. 1969; Hertzog et al. 1969) reported the cross-sectional decline in women between 35 years to 87 years to be 8.01 cm. The last mentioned two studies had subjects of wider age range *i.e.* up to ninth and 10th decades which is the probable reason for showing over all more declines as compared to some earlier studies where the age range did not go beyond seventies.

In India, a difference of 5.5 cm in migrant (Punjabi and Sindhi) group of women of Pune between mid- twenties to 70 years was noted. In the same study, sufficient data being available on 70+ age group for a population group of Maharashtrian Brahman women aged 20 years to 80+ years the mean decline in height was 14 cm, which is quite high (Bagga 1998). When the life styles of the migrant group of women under study were compared with the other local group of Maharashtra Brahman women, wide differences in lifestyles of the two groups, especially in food habits were observed, which could be partly responsible for the vast differences in linear declines. The migrants Punjabis and Sindhis who moved from Pakistan to Pune (India) in post- independence period (in 1947) traditionally consumed milk, yoghurt and other dairy products such as cottage cheese etc. daily as compared to the local Maharashtrian population which nurtures a strong belief that consumption of milk beyond childhood is not at all required by humans.

Another earlier similar study undertaken in India's Pune city comparing age changes in two groups of Maharashtrian Brahman women living with families with the other group of women living in old age homes showed decrements in stature beginning in fifth decade which increased in intensity in later decades, in both groups (Bagga and Sakurkar 2013). In women living with their families per cent declines in height (9%) were much more as compared to the declines observed in women living in old age homes (5%). One of the reasons could be differences in their activity level. Women living in old age homes were more mobile as they had to manage their own affairs largely consisting of cleaning, washing and maintaining their rooms, walking to the market for day- to-day purchases (fruits/biscuits/ bread/ butter etc) as some of them cooked meals in their own self- contained rooms. It is important to note that only women who did not have any major disease or disability were admitted to these old age homes and as mentioned earlier, they were expected to take care of their needs themselves. On the other hand, women living with their families largely depended upon their other younger family members to meet their basic needs and for running various errands for them, hence limiting their activity level in comparison to the other group.

In another well planned cross-sectional study (Devi and Bagga 2006) in north-east India, difference in mean height of agriculturist Meetei women of Manipur were 5.82 cm between the youngest (20-29 years) and the oldest age groups (80 years+). This difference increased to 7.82 cm in non- agriculturist Meetei women of Assam who had better household incomes and vastly different life styles.

Timing of reduction in height

The timing of reduction in height is important. Most of the investigators report the diminution to begin around 40-45 years (Friedlaender et al. 1977; Galloway et al. 1990; Bagga 1998; Hussain, unpublished; Devi and Bagga 2006; Bagga and Sakurkar 2013). In longitudinal studies individual changes of stature have been reported to begin by 42 years (Roche et al. 1981), 44 years in Swedish females (Noppa et al. 1980) and 45 years in Belgian males (Sussanne 1977).

In the current investigation a marginal decline was observed in the age group of 40-49 years reinforcing the assumption of the onset of decline in fifth decade. This finding supports previous observations of decline beginning by early to mid 40's to become noticeable by the 50's (Cline et al. 1989; Galloway et al. 1990). This would also imply that the age at onset of statural changes in the Indian women under study apparently do not differ much from other populations around the world. The onset of statural decline around mid-forties coincides with the period at which the rate of reduction of bone mass in women could start becoming perceptible during perimenopausal phase as the secretions of female hormones reduce in quantity appreciably, before actually menopause is achieved (Bagga 2004; Vaidya and Pandey 2004). Galloway et al. (1990) observed two major episodes of height loss in females, the first appearing around the late 50s, and the second coming later, after 75 years of age. Indian women showed a relatively sharper reduction in stature in sixties. Declines after 70 years of age are known to accelerate significantly and has been reported in many populations around the world (WHO 1995). Age changes beyond 70 years of age could not be attempted in the present study due to lack of suitable data.

Stature: Rate of Decline

Rate of decline in stature in Indian Maratha women under study was 1.2 cm per decade calculated for the ages from 30 to 70 years (Table 2). It was more than in an earlier study on urban Maratha (1cm/decade in sub-group Kunbi) women (Hussain, unpublished) but less than in the rural Maratha women (1.5 cm/decade), age range of study being wider *i.e.* from 23 to 80 years, and thus the rate of decline could be higher because decline is known to be faster after 70 years of age**.** Trotter and Glesser (1951) estimated the general rate of decline of 0.6 cm/decade and Noppa and associates (1980) reported a significant mean reduction of height at the rate of 0.4 cm/decade in their data. Himes and Muller (1977) found the rate of decline considerably more in rural Columbian males (1.2 cm/decade) than in females (0.3 cm/decade). Some studies do reveal higher rates of declines in women, more along the lines of those found in the present study. Dequeker (1969) reported a decline of 1.3 cm/decade while the highest mean decline of 1.5 cm/decade in subjects was reported by Galloway et al. (1990). Rates of decline in height in Indian (Maharashtrian Brahman) women were reported to be 2.33 cm/decade in women living with families and it was lesser (1.47 cm) in the same endogamous group of institutionalized women (Bagga and Sakurkar, 2013). In Migrant Punjabi and Sindhi women of Pune city who were used to regularly consuming calcium rich diet it was lesser, being 1.1 cm/decade (Bagga 1998). Among the agriculturist Meetei women of Manipur, rate of decline in stature was 0.97 cm per decade, it being slightly more (1.3 cm/decade) in non agriculturist Meetei women of Assam. As mentioned earlier, as the age-span increases such declines intensify because bone loss is fastest at the oldest ages (Devi and Bagga 2006).

The declines in linear measurements with advancing age in people are now well understood and are known to occur as a result of changes occurring primarily in the vertebral column. These may be actual age-associated changes such as vertebral body micro- chipping, compression of inter -vertebral discs, and kyphosis. In sitting height of women under study total percent decline was more than observed in their total height (stature), backbone accounting for a substantial decline supporting the hypothesis that the upper body remains the predominant site of age changes because of spinal compression and other such degenerative changes discussed above. Such changes being progressive in nature are bound to be more intense in older ages e.g. at age 70 and over, resulting in sharper declines then. If we calculate the rate from total decline from younger to older age, it evens out the differences. Therefore, it is suggested that evaluation of decade wise differences would be more suited in such studies; and it is equally important to match the age range before attempting any comparison in such studies.

It was also suggested that the cross-sectional studies over wide age ranges may have the problem of survivorship bias at the older ages (Borkan 1983). The hypothesis of a selective death rate, which might eliminate a disproportionate number of individuals of some particular type, in this case of taller individuals, was proposed by a few researchers (Eiben 1960; Clement 1974). It was, however, not supported by Laskar (1953) and Miall and his associates (1967), who do not consider the mortality of taller individuals to be a likely factor. Data from Parizkova and Eiselt's study (1980) also show that values of anthropometric measurements are not really significant in the prediction of morbidity and survival.

Postural change with age and its effect on height

Although decline in height with age can be explained largely on the basis of spinal compression, postural changes are also known to exert some influence. The lesser height declines in retired long-service army veterans as cited by Wood and Badley (1983) is an indication of the long term significance of posture. While the reduction in the vertebral column does not much affect the primary thoracic curvature, both the secondary curvatures are partially undone and stooping may occur. This is further accentuated by the increasing weakness of postural muscles which stretch across the secondary curvatures, partly because of the reduction in the distance between the origin and insertion of the muscles (Sinclair 1989), and partly due to the general atrophy and neglect of all trunk muscles with age (Roaf 1977). Hence it is probable that bent posture accounts for a portion of the observed shrinkage of stature in older populations. This is particularly important when occupation demands constant bending as observed among agricultural laborers particularly in less developed countries, while working in the fields for their routine agricultural activities such as sowing, harvesting, weeding etc.

Declines in stature and kyphosis with age are largely correlated with osteoporosis. As discussed above, the decrease in total and sitting height is the direct result of degenerative changes occurring predominantly in the vertebral column. As vertebral bodies become osteoporotic their structure renders them more liable to collapse than other bones. Moreover, molecular and histological changes in the vertebral discs begin around 45 to 50 years or even earlier, result in the discs becoming progressively dehydrated and pigmented, to finally collapse under the strain. The compression results in decrease in height, chiefly as a result of change in the lower part of the vertebral column which takes the greatest gravitational load (Sinclair 1989; WHO 1998c).

Body weight is an important determinant of bone mass, and bone loss in postmenopausal women has been found to be more rapid especially in women who have lesser bone mass. The protective effect of body weight on bone mass is also due to the mechanical effects of body weight on bone formation (Francis 1992). Osteoporosis is an established factor known to contribute to the reduction in body weight at older ages. Women patients in mental hospital from where data were collected had lesser body weights at all ages. Most of them were lethargic often under the influence of essential drugs.

Secular Trend

Existing literature shows great variation in the reports concerning secular trend. Most western countries have been reporting not only a secular trend toward increased height, but also a slackening and stabilization of this trend in recent times. This tendency is reported to be either absent or less evident in rural and tribal communities and populations from the less developed countries (Ulijaszek et al. 1998). For instance absence of a secular trend in adult statures has been reported in rural Mali (Prazuck et al. 1988), rural Columbian women

(Himes and Muller 1977), and rural Irish women (Relethford and Lees 1981). Previous studies indicate that secular changes in adult stature in the rural population studied, on the whole, may be extremely small, if at all. Since a general relationship is believed to exist between technological advancements and increase in stature due to overall socio-economic conditions and consequently improved nutrition, educational and medical facilities, there is a good possibility that such changes have not yet affected people living in backward or underdeveloped or yet developing countries to an extent where it could have brought about a consistently significant difference in body dimensions (Eveleth and Tanner, 1990; Bagga and Kulkarni, 2000).

Earlier, Borkan et al. (1983) examined 10 years' multi-cohort longitudinal data on height, arm span and their component segments to conclude that 4.27 cm (61%) out of the overall 7.27 cm difference in height between the youngest and oldest groups could be explained by ageing changes, while 3.00 cm (39%) was due to the secular trend. Cline at al (1989) also concluded that approximately 60% of the smaller stature of older male subjects and 45% of the smaller stature of older female subjects was a birth cohort effect deriving from the secular trend toward greater stature; the remainder was a result of an actual decrement in height after the age of 40. Analysis of the present data showed that 70.83 percent (2.55 cm) of the statural difference in women of the present study was in the upper half of the body due to ageing effect, remaining 29.17 percent (1.05 cm) of the total 3.6 cm could have been due to the secular gain in height in the younger generation.

Conclusion

Morphological age changes seem quite complex as they are influenced by several internal and external factors, mechanical effects of use and wear, and physical stress during the lifetime of an individual, making the task of such assessments quite complicated. Despite these limitations, studying such age changes in populations having diverse cultures and lifestyles can be of immense significance adding to the knowledge of biology of ageing. With much increased human longevity in recent decades, cross-sectional and longitudinal studies with wider age ranges will reveal regional population differences and their possible causes helping understand them better, using such knowledge towards healthier ageing of populations.

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