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Stature Loss Among an Older United States Population and Its Relation to Bone Mineral Status

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ABSTRACT Age-related statural loss has been recorded but incompletely assessed in modern populations. In this study, data collected on stature during annual bone mineral assessments are analyzed for 1,024 Caucasian individuals from southern Arizona. Continued stabilization in reported maximum heights is seen in this population. With advancing age there is a gradual decrease in height apparently beginning in the mid-40s. Thereafter, there is a relatively rapid decrease in measured height. This contrasts to the much slower rates predicted from earlier populations (Trotter and Gleser: *American Journal of Physical Anthropology* 9:311–324, 1951). The rate of stature loss is associated with diminution of bone mineral density as well as with maximum height. Since there are suggestions of a secular trend toward greater reductions in bone mineral density, this study suggests there may be a secular trend toward an increase in statural loss with age.

Loss of standing height is a feature of the aging process that is commonly known but has been incompletely assessed in a modern, living population. Maximum height, itself, has been documented as changing considerably over the last century in response to improved nutrition and health (Stoudt et al., 1965; Garn, 1969; Damon, 1968). Toward the second half of this century, however, the increase has appeared to slacken or cease (Bakwin and Mclaughlin, 1964). The effects of these secular trends for increase and stabilization in adult height on age-related statural loss in the later years need to be assessed.

Acknowledgment of reduction in stature has been widely adopted by skeletal biologists. Using the Terry collection, Trotter and Gleser (1951) discussed compensation in height calculated from long bones necessary to accommodate age changes. Arbitrarily choosing 30 as the age of onset of stature reduction, they developed a correction formula, 0.06 cm $\times$ (age$-$30), to be subtracted from the calculated height. The skeletal series, however, from which this study is drawn, consists of individuals ranging in age from 19 to 91, who were born in 1840 or thereafter, well before the stabilization of the secular trend for increased height. In addition this sample is weighted toward those of lower socioeconomic levels (Jantz and Moore-Jansen, 1988). Females, though included in the study, are not fully discussed as female sample sizes were considerably reduced when separated by racial group.

The present report concentrates on the documentation of stature loss in a living, non-institutionalized Caucasian population in the United States, and on the relation of this loss to changes in bone mineral status.

MATERIALS AND METHODS

The statistical population used in this analysis is drawn from three communities in southern Arizona as part of a mixed longitudinal study. This population is restricted to Caucasoid individuals in order to limit racial differences in bone mineral status and change. Included are a total of 1,024 individuals (735 female, 289 male). The amount of

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data available for each subject varies (Table 3). Ages range from 50 to 92 years with a mean age of 70.1 years (SD 7.3) for the women and 70.8 years (SD 6.5) for the men. The subpopulations are from the communities of Sun City, Tucson, and from Casa Grande and the surrounding towns of Florence and Eloy. None of the subjects are restricted to institutionalized care.

The Sun City population (301 females, 168 males) includes retirees largely from professional occupations and their spouses. The community, an affluent retirement development west of Phoenix, espouses an active lifestyle with abundant recreational activities. The subjects involved in this project were recruited through the assistance of the Boswell Hospital Volunteers Office and Hospital Auxiliary, to which many of the participants belong. The subjects tend to be in good health, ambulatory, and involved in extensive athletic and community programs.

The Tucson subpopulation (336 females, 90 males) was drawn from a number of public housing facilities and the Armory Park Senior Center. Recruitment was organized by Project AgeWell, Family and Community Medicine Section of the Arizona Health Sciences Center. The subjects, particularly those in subsidized housing, tend to be less affluent than those in Sun City. While most are in relatively good health upon entry into the program, there is a higher frequency of health concerns. Furthermore, a small portion of this group is semi-ambulatory.

The subpopulation from the Casa Grande area (98 females, 31 males) was recruited through the Pinal County Health Department. The subjects tend to be of moderate socioeconomic status, independent, and ambulatory. Many continue to be fully employed past the usual retirement age of 65.

The purpose of this project is the annual monitoring of changes in bone mineral status. Six annual scans had been completed at the time the current data set was compiled. Subjects are encouraged to continue their participation in the project, even if they could not be scanned every year. In addition, new subjects are admitted to the study each year.

Table 1 shows the distribution of subjects by the number of intervening years between their first and last scans. It is this distribution that permits the calculation of the percentage of change in height and bone mineral values on an annual basis.

TABLE 1. Population distribution by length of time in study (number of years between first and last scans)

	Single scan	Year 1	2	3	4	5
Female	319	160	70	46	70	70
Male	151	39	29	13	13	44

ANTHROPOMETRIC MEASUREMENTS

All individuals who are capable of standing are measured, without shoes, heels together at standing stretch height. A Gneupel/GPM free-standing anthropometer is employed for these measurements, the majority of which were taken by a single person (W.A.S.). Height is recorded to the nearest millimeter. Height measurements were not taken during the first 2 years of the project.

Prior to measurement, questionnaires are distributed to all subjects requesting current and maximum height in English units. Maximum height is explained as height at age 25, or the greatest height remembered. Annual height change is calculated as the difference between the first and last height measurements divided by the number of intervening years. Loss of height is calculated as the difference between reported maximum height and the first of the measured heights and expressed as a percentage of reported maximum height.

BONE MINERAL ASSESSMENT

The bone mineral examinations from 1982 to 1987 were conducted by using a Lunar Radiation SP1 single-photon absorptiometer. In July 1987, this model was replaced with an SP2 single-photon rectilinear scanner, which was used in all further examinations. A correction factor was used to equate the SP1 scans to those of the SP2.

The site chosen for study is the one-third distal point of the left radius. This point reflects primarily cortical bone (85–90%) and is roughly circular in cross section (U.S. NCHSR and HCTA, 1986). The scan site is obtained by measuring the ulna from its most distal palpable point to the olecranon process. From this length, the one-third distal point is calculated for the radial scan.

Each scan includes four passes, the results of which are averaged. All scans by the SP1 model were taken at a single point. For the

SP2 model, this procedure has been replaced by a rectilinear scan, in which the four passes are each separated by 3 mm. All scans are conducted at 1 mm/sec, and in all cases, the subject's arm is enclosed in a gel tissue equivalent for the duration of the scan. This latter procedure helps determine a baseline.

The results are proved in three measurements: bone mineral content (BMC), bone width (BW), and bone mineral density (BMD). BMC is measured as grams per centimeter. BW is given in centimeters. BMD, determined by dividing BMC by BW, is given as grams per square centimeter. Due to the two-dimensional nature of the measurement, a true density can only be approximated.

The annual change is calculated for each of these values by using the difference between the first and last scan, expressed as a percentage of the first value and divided by the number of intervening years.

Finally, a comparison to normative values for BMD is calculated with the SP2 scans. These values are expressed as a comparison with 1) sex-matched young (ages 20–50 years), healthy normative values, and 2) with sex-matched, age-matched, normative values. The age-matched values are derived from a linear regression function provided with the software for the SP2 model.

TABLE 2. Mean and standard deviation (in parentheses) of the initial bone mineral content (BMC), bone width (BW), and bone mineral density (BMD) for females and males by age group

	N	BMC	BW	BMD
Female				
Total	735	.672 (.14)	1.230 (.12)	.548 (.10)
50–54	11	.816 (.16)	1.190 (.13)	.691 (.10)
55–59	34	.755 (.11)	1.217 (.13)	.626 (.09)
60–64	131	.731 (.12)	1.224 (.11)	.599 (.09)
65–69	174	.686 (.13)	1.233 (.12)	.558 (.10)
70–74	192	.656 (.13)	1.237 (.12)	.530 (.09)
75–79	104	.639 (.14)	1.239 (.14)	.519 (.09)
80–84	67	.589 (.12)	1.221 (.13)	.485 (.09)
85–89	22	.554 (.09)	1.218 (.09)	.456 (.08)
Males				
Total	289	1.102 (.19)	1.511 (.15)	.727 (.11)
50–54	3	.813 (.69)	1.181 (.78)	.539 (.43)
55–59	5	1.191 (.13)	1.554 (.18)	.762 (.06)
60–64	34	1.103 (.17)	1.511 (.14)	.730 (.11)
65–69	82	1.117 (.17)	1.506 (.15)	.740 (.08)
70–74	85	1.114 (.16)	1.510 (.13)	.737 (.10)
75–79	56	1.140 (.16)	1.546 (.11)	.736 (.09)
80–84	18	.976 (.18)	1.467 (.12)	.666 (.12)
85–89	4	.898 (.14)	1.467 (.13)	.587 (.07)
90+	2	.696 (.38)	1.605 (.02)	.428 (.24)

ANALYSIS

Analysis is conducted by using the SPSS-X program (SPSS, Inc., 1988) on the University of Tennessee VAX cluster. Basic descriptive statistics are generated by using groupings based on the variables of age, height, and bone mineral density. In addition, linear regression and t-tests are used to test the significance of intragroup and intergroup trends. Finally multiple stepwise regression functions are generated in order to evaluate the roles of the variables in the reduction of stature.

RESULTS

The results (Table 2) from the first scan of each subject show that there are significant declines in Bone Mineral Content (BMC) and Bone Mineral Density (BMD) in both sexes with increased age. This decline is primarily found in females ($P = .000$). While the decline in males is not statistically significant for BMC ($P = .07$), the BMD values attain significance ($P < .05$). The results for males suggest little difference in bone width (BW). In females, however, there appears to be a very slight increase in bone diameter ($P = .05$).

Correlation matrix of all variables is shown in Table 3. Since BMD is determined from BMC and BW, significant correlations are expected between these variables. Changes in BMC and BW are positively correlated, suggesting that both tend to increase simultaneously. An increase in BW is significantly linked to a decrease in BMD. The results show that an increase in BW is linked to a decrease in BMD, while an increase in BMC is associated with an increase in BMD. The results also show that it is females who most often experience a reduction of BMD associated with an increase in BW ($r = -.3706, P = .000$), even though the values for BMC either remain constant or actually increase (Table 4). The annual changes of BMC exhibit a significant positive correlation with both young normative and age-matched normative values (Table 3). Annual change in BW does not correlate significantly with either normative value. While most women experience an annual loss of BMD (overall average = −0.66%, SD 5.7), women with the lowest bone mineral status (n = 20), whose BMD is less than 0.4 gm/cm^2, exhibit a nonsignifi-

TABLE 3. Correlation matrix for all variables included in this study (numbers of observations in parentheses)

	BMC	BW	BMD	% of young norm	% of age norm	Ht	BMC chg	BW chg	BMD chg	Ht chg	Max ht	Total % chg from max	% annual ht chg from max
Age (1024)	− .139**	—	− .249**	− .293**	—	− .170**	—	—	—	—	—	− .388*	—
BMC (1024)		.723**	.899**	.745**	.537**	—	− .072*	− .121**	—	.123*	.721**	.116**	—
BW (1024)			.423**	.240**	.077*	.606**	− .111**	− .209**	—	—	.674**	—	—
BMD (1024)				.908**	.734**	.583**	—	—	—	.136**	.579**	.186**	.095**
% of young norm (1024)					.883**	.407**	.282**	− .105*	.371**	—	.382**	.226**	.095*
% of age-matched norm (1024)						.192**	.286**	− .088*	.354**	—	.210**	.115*	.105*
Current height (933)							—	− .118*	.104**	—	.936**	.270**	.206**
BMC change (554)								.377**	.684**	—	—	—	—
BW change (554)									− .372**	—	− .131**	—	—
BMD change (554)										—	.093*	—	—
Height change (327)											—	—	− .134*
Maximum reported height (690)												− .086*	− .108*
Total % height change from maximum (619)													.875**

$*< .05$.
$**< .001$.

TABLE 4. Mean and standard deviation (in parentheses) of the annual percent change in bone mineral content (BMC), bone width (BW), and bone mineral density (BMD) for females and males by age group

	N	BMC change	BW change	BMD change
Females				
Total	416	1.046 (6.0)	1.823 (4.6)	− .658 (5.7)
50–54	4	4.009 (3.8)	1.569 (2.4)	2.345 (2.6)
55–59	21	1.023 (2.8)	.543 (2.3)	.777 (3.3)
60–64	68	2.567 (5.8)	1.936 (4.1)	.636 (5.3)
65–69	97	.267 (5.6)	1.838 (4.5)	− 1.383 (6.3)
70–74	113	1.251 (7.0)	1.615 (4.9)	− .325 (4.7)
75–79	68	.260 (5.4)	2.386 (5.8)	− 1.922 (6.9)
80–84	36	.946 (6.4)	1.979 (3.5)	− 1.074 (6.2)
85–89	9	.468 (6.9)	1.652 (3.1)	− .285 (6.2)
Males				
Total	138	.529 (3.3)	.500 (2.6)	.269 (3.3)
50–54	1	− .147	2.841	− 2.627
55–59	16	1.335 (2.2)	.744 (1.5)	.978 (1.7)
60–64	36	.634 (3.5)	.474 (3.0)	.402 (3.4)
65–69	42	.643 (3.2)	.496 (2.2)	.465 (2.7)
70–74	33	− .216 (3.3)	.250 (2.9)	− .153 (4.5)
75–79	10	.925 (4.6)	.813 (3.6)	− .494 (3.1)

cant tendency toward an annual increase in BMD (average +.9%, SD 7.5).

Secular trends in current and reported maximum height

There is little evidence for a secular trend in reported maximum height. Mean reported maximum height for women is virtually unchanged, while that for men shows a slight rise of about 3 cm, followed by a decline of 4 cm (Fig. 1). This decline, however, is not significant.

The current measured height data do show a statistically significant decline in the mean values of females (Fig. 2). For males only a slight decline is seen in current mean heights ($P = .015$).

The total change of height, expressed as a percentage of reported maximum height, shows an increase of loss with age in both sexes. In those subjects over age 70, the average loss is 2.9% for females and 2.8% for males. Linear regression of total loss in stature by age shows an intercept for the onset of loss at age 45 years (Fig. 3).

Annual changes in height

There are two ways of computing annual rates of change in height. First, annual change in height may be calculated from the annual measurements though the results exhibit great variability (Table 5). The mean

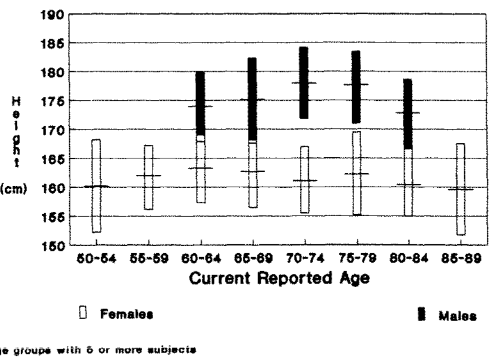

Fig. 1. Means and standard deviations of reported maximum height (cm) by age for males and females.

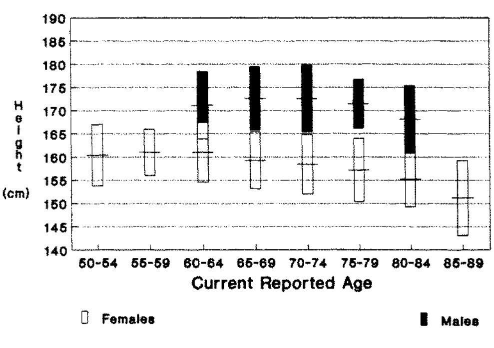

Fig. 2. Means and standard deviations of current measured height for males and females by age.

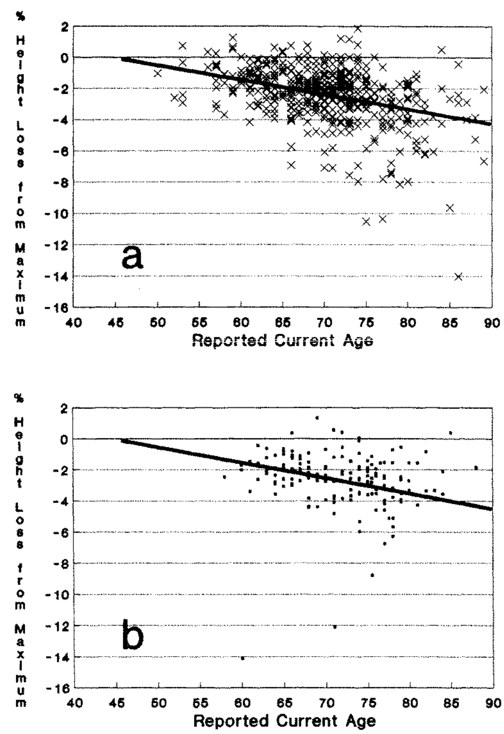

Fig. 3. Individual values of total height reduction from maximum, calculated as a percentage of maximum reported height, for females (a) and males (b) by age. Regression lines indicate slope of change for each sex.

loss in females is 0.1% per year, while in males, the loss is less, averaging 0.02% per year. The males do not exhibit any specific trend, while females tend to exhibit greater increases in height loss during their later years, particularly after age 75.

Second, change in height may be calculated on an annual basis with respect to the reported maximum height by using the intercept of 45 as the onset age of statural loss. Using this method, average annual height loss is calculated at 0.09% in females and 0.10% in males. There is no significant difference between the sexes in the annual rates of loss derived in this manner. An increase in rate of height loss among older women is still apparent.

Correlation with bone mineral status

Total loss of height calculated from reported maximum height appears greatest in those subjects with the lowest bone mineral values. For women whose bone mineral density (BMD) is less than 0.05 gm/cm^2, the average loss of height is greater, falling below the mean total loss. In males, the total loss also is greatest in those individuals with low BMD values. The annual rates of height change also reflect these trends, particularly in females (Fig. 4). The annual percentage loss calculated from maximum height indicates that those subjects with low bone mineral values lose height substantially faster than those with greater bone mineral values (P = .001 for both sexes). The percentages of both total and annual loss of height, calculated from maximum height, are significantly correlated with the normative values.

TABLE 5. Mean annual changes in height within each age group (standard deviations in parentheses)

	N	Measured annual height change	N	Calculated annual percentage of height change from maximum beginning age 45
Female				
Total	237	− .107 (.50)	459	− .094 (.08)
50-54	2	− .038 (.15)	6	− .202 (.19)
55-59	17	− .313 (.71)	22	− .090 (.10)
60-64	30	.004 (.19)	70	− .083 (.10)
65-69	56	− .013 (.37)	109	− .093 (.06)
70-74	64	− .064 (.44)	135	− .087 (.07)
75-79	40	− .205 (.69)	68	− .110 (.07)
80-84	23	− .238 (.62)	37	− .095 (.05)
85-89	5	− .296 (.50)	12	− .114 (.09)
Male				
Total	90	.023 (.42)	160	− .105 (.09)
50-54	1	.150	1	− .112
55-59			2	− .117 (.10)
60-64	11	− .033 (.13)	18	− .160 (.20)
65-69	23	− .019 (.17)	43	− .101 (.06)
70-74	28	.106 (.67)	48	− .100 (.08)
75-79	21	− .007 (.28)	37	− .076 (.04)
80-84	6	− .012 (.36)	9	− .076 (.03)
85-89			2	− .017 (.04)

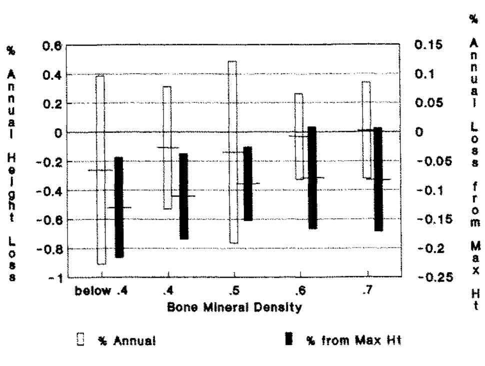

Fig. 4. The reduction in height calculated as a percentage of the first measured stature and from the reported maximum height using an onset age of 45 in females by the bone mineral density (BMD) at the radial midshaft.

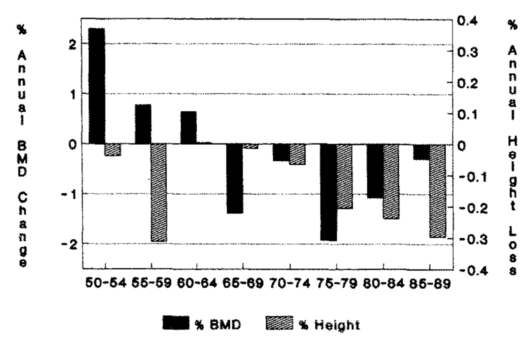

Fig. 5. Mean annual percent changes in bone mineral density (BMD) and measured height in females.

The timing of height loss also appears critical. In females, there are two major episodes of height loss. The first appears in the later 50s and is produced by a few women who exhibit a drastic rate of loss. This is witnessed by the sharp increase in standard deviation in the 55–59 year age group (Table 5). The second episode is in the later years, after age 75 (Fig. 5). Annual decreases in BMD at the radial midshaft do not occur regularly until the later years, after age 65.

Height itself is positively correlated with the bone mineral status. Taller subjects tend to have high bone mineral values (Fig. 6). In these tall subjects, bone mineral content (BMC), bone width (BW), and bone mineral density (BMD) are all greater than the corresponding values of shorter subjects. The normative values also significantly correlate with the height measurements taken at the beginning of the study, as well as with reported maximum height.

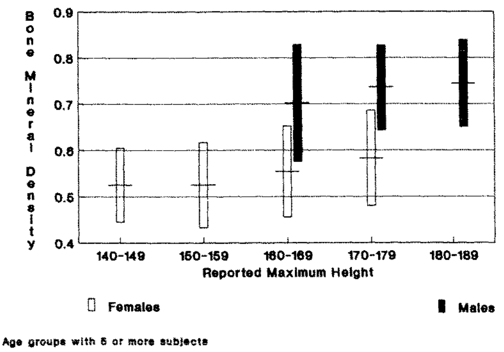

Fig. 6. Means and standard deviation of bone mineral density (BMD) for males and females by their reported maximum height.

Multiple stepwise regression functions conducted by using age, reported maximum height, and BMD suggest that, of these three variables, BMD plays the largest role in determining annual stature reduction. The explained variance, however, is low ($r = .108$, $r^2 = .011$), and can only be minimally increased with all three variables included ($r = .234$, $r^2 = .055$). The percentage of total stature reduction depends, primarily, on age ($r = .338$, $r^2 = .114$) although maximum reported height and bone mineral also appear to play a role (combined variables $r = .399$, $r^2 = .159$).

DISCUSSION

Measurement of stature in the elderly has received considerable attention (Buchi, 1950; Trotter and Gleser, 1951; Miall et al., 1967; Hertzog et al., 1969; Himes and Mueller, 1977; Borkan et al., 1983; Chumlea et al., 1988; Cline et al., 1989), yet the effects of aging have been difficult to separate from secular changes. Even the measurement of stature itself in the elderly is subject to problems of replication (Chumlea et al., 1984). The measurement of stature in females is particularly prone to significant inter-observer errors.

In addition, there are problems in the use of reported heights that must be acknowledged. Both Boldsen and colleagues (1986) and Willey and Falsetti (1987) report that shorter individuals tend to exaggerate their height, while taller people tend to underestimate their height. It also has been shown that a majority of older people do not fully recognize the extent of their own height loss (Galloway, 1988). Most estimate that they may have lost no more than one-half to 1 inch.

The lack of secular trend for increased reported maximum stature among this contemporary older population is beneficial in the evaluation of age-related height change. This finding is consistent with other studies that suggest a slackening and stabilization of the trend toward increased maximum stature among Western populations (Bakwin and Maclaughlin, 1964; Damon, 1968). A population in which mean maximum attained height remains stable is essential for assessment of stature loss in older individuals.

The age of the onset of stature loss has traditionally been set at 30 (Trotter and Gleser, 1951), and this figure has been used in a number of studies on stature loss. During the years immediately following age 30, loss appears to be minimal. In an effort to separate actual vs. secular differences in stature, Hertzog and associates (1969) plotted heights estimated from tibial length. Although they use age 30 as the point of onset, notable decreases in stature do not become apparent in their 52 test females until ages 50 to 59.9. A late onset of substantial stature loss is suggested by Buchi (1950), who proposes an age of 47 years. Friedlaender and colleagues (1977) suggest that stature loss first becomes apparent in the 40–44 year-old cohort of U.S. white males. The more recent work by Cline and colleagues (1989), based on a large population, also from southern Arizona, suggests an onset of stature reduction of 40 years for males and 43 years for females. The present study is in agreement with these works in finding that severe loss of height appears to begin in the early to middle 40s, probably becoming noticeable by the late 50s.

Rather than use the absolute values of statural loss, percentage of maximum height is used in the present study. Therefore, a correction factor for height in the older individual may be calculated at ($0.09\% \times$ maximum height) $\times$ (age $-$ 45). Since the average reported maximum height for women is 162.3 cm, the mean loss per year is 0.146 cm/yr. In males average reported maximum height is 172.2 cm, resulting in a mean loss of 0.155 cm/yr. Alternately, height can be adjusted by subtracting the absolute values calculated according to the following formulae from the maximum height:

1. (((age − 45) × .10) − .03)/100 × maximum height
2. (((age − 45) × .09) − (BMD × 1.61) + 1.14)/100 × maximum height
3. (((age − 45) × .10) + (maximum height × .02) − 3.41)/100 × maximum height
4. (((age − 45) × .08) − (BMD × 3.70) + (maximum height × .05) − 5.6)/100 × maximum height

The rate of loss in the present analysis is substantially higher than that of 0.06 cm/yr proposed by Trotter and Gleser in 1951. Other studies also suggest higher rates of loss. The data presented by Hertzog and colleagues (1969) show that the rate of loss reported in their calibration cases is close to the 0.06 cm/yr in the younger of their categories. In their test sample, females measured at age 30, and again at age 45, showed a 0.14 cm loss, averaging 0.009 cm/yr (assuming an onset of loss at age 30). This mild rate of loss is corroborated by Himes and Mueller (1977). In women, their rates were 0.01 cm/yr for high socioeconomic status and 0.09 cm/yr for low socioeconomic status. Higher rates of loss were found in males: 0.09 cm/yr with high socioeconomic status and 0.14 cm/yr for low socioeconomic status. Their age distribution, however, reveals that 52% of the males are over 45 years of age, while only 24% of the females are in this older age bracket. Borkan and associates (1983) assume only small reductions in stature before age 50. In fact, this assumption was then used to correct for inter-observer error.

Hertzog and colleagues (1969) report that rates of height loss increase to 0.11 cm/yr after age 45 for women measured at approximately age 30 years and again at age 55 years. If calculated at an onset of age 45, this is equivalent to a rate of height loss of 0.16 cm/yr but only 0.04 cm/yr if using age 30. The rates of loss for males in this study tend to be slightly lower. Cline and colleagues (1989) found that the rate of loss increased from 0.06 cm/yr around age 55 in both sexes to 0.18 cm/yr for males and 0.23 cm/yr for females by age 85. In contrast to these rates, Chumlea and associates (1988) claim a stature loss in both sexes of 0.5 cm/yr, far greater than found in other published reports. They found this rate to be constant in their sample, which ranged in age from 65 to 89 years.

The reevaluation of the earlier studies, in conjunction with the results of the present study, suggests that a relatively small loss of stature may occur after age 30. Beginning in the mid-40s, however, the rates of loss increase. The present study also suggests that the annual loss of height is particularly severe in older women and in those with low BMD.

The results for males are ambiguous, as the rates calculated from maximum height are approximately equivalent to the averages of those for the females while the change calculated from the annual measurements is considerably lower. This discrepancy may be accounted for by the biphasic nature of stature loss in the females. Faulty recollection or exaggeration of maximum reported height toward socially preferred statures (Willey and Falsetti, 1987) may also be partly responsible for the discrepancies in male height loss calculations.

Much of the loss of height appears to be part of the usual aging pattern. Borkan and colleagues (1983) have compared standing height, sitting height, lower body height, knee height, and armspan. Their results show that 66% of statural loss occurred in the upper body, which constitutes only 52% of total stature. Part of this loss may be accountable to the intervertebral disks, which are known to compact with age, to stiffen, and become more fibrous. In youths, the intervertebral disks form approximately 20–30% of the total spinal length. As individuals age this proportion is reduced, causing an overall loss in stature.

The aging process alone cannot fully explain the incidence of stature reduction. Adverse changes in bone mineral content can lead to vertebral body collapse or wedging. While the present study monitors cortical bone, it is generally assumed that, in most individuals, there is a primary loss of trabecular bone. For this reason, clinical use of the peripheral site in bone mineral assessment is not widely advocated since such use produces a large number of false negatives for bone loss. If, however, the cortical bone exhibits reduction, then it is likely that trabecular bone has already undergone serious losses as well.

The present study supports the hypothesis linking statural loss to reduction in bone mass. Those individuals with below-average bone mineral density at the radial site tend to have lost significantly more height than individuals with greater density. Stepwise multiple regression analysis also emphasizes the role of bone mineral status in determining the total and annual rate of bone loss.

This hypothesis is also supported by the profile of height loss among women. There appears to be an episode of height loss experienced by at least some women in their later 50s. This would coincide with the major decreases in trabecular bone seen postmenopausally (Lindquist et al., 1983; Ruegsegger et al., 1984; Johnston et al., 1985; Riggs and Melton, 1986; Raisz and Smith, 1989). A second episode of height loss begins in the later years, coinciding with a loss of bone in a much broader segment of the older population (Raisz and Smith, 1989).

The possibility of a secular trend toward an increased rate of stature loss must be considered. Bengner and colleagues (1988) have reported a higher incidence of vertebral fractures in a comparison of radiographs over a 30 year span. They report that the incidence of symptomatic vertebral fractures in women over age 80 has approximately quadrupled and that the increase in males is even greater. Not only is the frequency of fracture greater, but the degree of damage may also be higher. Riggs and Melton (1988) report that one-third of women over age 65 will have vertebral fractures. Similar trends for hip fractures, also linked to osteopenia, have been reported by Melton and others (1987).

The discrepancy between studies discussed above may be due, in part, to differences in sex distribution between samples. While the study by Trotter and Gleser was mainly composed of males, the present analysis is primarily of females. It has been shown that females, with drastic postmenopausal losses of bone mass, tend to be more susceptible to vertebral fractures (U.S. NIH, 1984). This would lead to direct statural loss as well as postural changes. This is evident in the present sample. A high rate of loss, however, was also seen in the males in the present study when calculated from reported maximum height. Other studies (Hertzog et al., 1969; Borkan et al., 1983) do not support a comparable loss between males and females. This may be partly due to sample distribution, for the aim of the present study has been directed at females. It may also be due to the secular trends in vertebral fractures discussed above.

SUMMARY

Older individuals undergo a stature reduction of approximately 0.09% per year, based upon reported maximum height and upon measurements of standing stretch height. The age of onset for this rate of loss appears to be approximately 45 years. In females, there appears to be a biphasic loss with an initial postmenopausal episode followed by a longer episode becoming apparent after age 75. Height loss among those with low bone mineral values, assessed by single-photon absorptiometry at the midshaft of the radius, is particularly high, and progresses at a significantly faster rate than in those with greater bone mineral density. Although the secular trend for increased height appears to have stabilized, a secular trend for increased age-related statural loss may be surfacing.

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