The rate of decline in stature with age as a measure of health status and physical fitness of elderly people: a preliminary study

**INTRODUCTION**

Age-related changes involve virtually all morphological and physiological traits of the human body [23, 26]. Adult stature is viewed as a single physical characteristic...
which enables researchers to cursorily assess the biological condition of the organism as it correlates positively with socioeconomic status (SES), social mobility, remuneration, health, and physical attractiveness of men in Western countries [4, 28]. Body height decreases with increasing age as a result of the progressive curvature of the spine, the osteoporotic collapse of the vertebrae, and other postural changes or deformities, including loss of muscle tone and platypodia [3, 5, 23, 24, 34–36]. The age-related reduction in height develops silently in the third decade of life and accelerates gradually in the subsequent decades even in individuals who continue to be physically active [5, 25, 27, 31]. Although it is a normal part of the aging process, the increased pace of reduction in height may be linked to a variety of health problems. Therefore, the rate of the age-related decline in adult stature is considered to be potentially informative in terms of general health, occurrence of osteomalacia, osteopenia, osteoporosis, risk of future osteoporotic fractures, physical frailty, and falls [5, 6, 9, 10, 12, 34]. In elderly people, senescence is associated with weakness, fatigue, postural instability, frailty, falls, and fractures. These health problems pose a serious threat to quality of life in older people and may shorten life expectancy [17].

MATERIAL AND METHODS

We have used data on health profiles and changes with age in body height from the Polish Longitudinal Study on Aging (PLSA) carried out in the years 1960–2000 at the Regional Psychiatric Hospital in Ciborż, Lubuskie Province, Poland. The PLSA was a long-term prospective investigation which followed asylum inmates. Out of the total number of patients who lived at the hospital for many years (N=3,500), we have selected data from 142 physically healthy inmates, including 68 men and 74 women, whose health was evaluated longitudinally for at least 25 years, starting from the age of 45 onwards.

All methods and techniques were in accordance with internationally accepted standards and requirements. Measurements of body height were taken when a subject was standing in light indoor clothing, without shoes. Height was measured to the nearest 0.1 cm using a standard stadiometer. It is noteworthy that the patients lived for many years under identical and relatively good environmental conditions, which undoubtedly boosts the value of the study sample. During their stay at the hospital, the inmates would take some powerful psychoactive drugs. Therefore, we have carefully selected solely data from patients who hardly ever had been treated with strong medicines or who had been treated so every once in a while. Main causes of death were predominantly aging-associated diseases such as ‘cardiorespiratory failure’ (CRF), cardiovascular disease (CVD), stroke, and cancer.

The sample was divided into 3 categories of the rate of height loss, i.e. HL<1.0 cm/decade, 1.0–2.9 cm, and ≥3.0 cm/decade (Table I). To compare health profiles and the rates of changes with age, ANOVA, t-test, and regression analysis were employed.
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Table I. Number of subjects from the PLSA by rate of height loss per decade

<table>
<thead>
<tr>
<th>HL (cm)</th>
<th>Men</th>
<th>Women</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>1–2.9</td>
<td>51</td>
<td>58</td>
<td>109</td>
</tr>
<tr>
<td>≥3</td>
<td>11</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>Σ</td>
<td>68</td>
<td>74</td>
<td>142</td>
</tr>
</tbody>
</table>

RESULTS

The subjects with low, average, and high rate of reduction in height (i.e. HL<1.0 cm/decade, 1.0–2.9 cm, and ≥3.0 cm/decade, respectively) differed in the rates and patterns of age related changes in body height (ANOVA, p<0.05). Moreover, the patients differed also in a number of important indicators of physical fitness, health, morbidity, all-cause mortality, cause-specific mortality, and survival probabilities (Fig. 1). Taller subjects (BH>median; 169.5 cm for men and 155.8 cm for women, Table II) and those who lost less height (HL<1 cm/decade) lived significantly longer compared with shorter subjects and those who had a substantial reduction in height (ANOVA, p<0.05). HL≥3.0 cm/decade in older men and women was associated with an increased risk of all-cause mortality as well as CRF, CVD such as coronary artery disease (CAD), i.e. coronary heart disease (CHD) but not with stroke. There was no clear connection between elevated rate of HL and risk of cancer. However, substantial loss of height correlated positively with the prevalence of osteoporosis, osteoporotic fractures, mobility problems, hypokinesia, and musculoskeletal disorders (MSDs). These associations were particularly noticeable in elderly individuals who had higher rate of loss of height.

Table II. Number of subjects according to sex and category of body height

<table>
<thead>
<tr>
<th>Sex</th>
<th>Taller</th>
<th>Shorter</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>34</td>
<td>34</td>
<td>68</td>
</tr>
<tr>
<td>Women</td>
<td>37</td>
<td>37</td>
<td>74</td>
</tr>
</tbody>
</table>
DISCUSSION

The Polish people are living longer, thereby participating in the so-called process of ‘greying of the world population’. Currently, the number of people aged 60 and above makes up a larger share of the Polish population than ever before. This number is expected to double by the year 2050. Moreover, for the first time, the number of elderly people is close to surpass the number of children. Therefore, the aging process has become both a challenge and one of the central issues in current biology (gerontology) and medicine (geriatrics). The increase in the number of older people poses a formidable problem for medicine and financial policy from a global perspective.

There has been a growing interest in evaluating biological condition of older people because there is little information on rates and patterns of the aging process concerning elderly people confined to medical institutions [6, 17]. Every old person experiences the accumulation of deleterious changes over the course of life but the process of aging is to some extent malleable, which means that it is shaped by past events and experiences [17]. A growing body of evidence suggests that behaviour is one of the most important determinants of future health outcomes in physically healthy individuals who do not have genetic predispositions towards severe diseases [18]. Thus physical activity is associated with health in its broadest sense, i.e. somatic and mental. The pattern of changes with age in physical fitness is not unlike that of other physical dimensions of the human body as it reaches a peak in the second or third decade of life and begins to wane thereafter [4]. However, the rate of decline with age depends on physical activity, diet, nutrition, stress level, amount of sleep, and other components of lifestyle [10, 23].
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Body height is achieved as the result of the complex and dynamic interplay between genetic and environmental factors [4]. Although genetic inheritance is definitely the major component of variation in stature, extrinsic factors and lifestyle have a substantial contributory effect. Resemblances in stature between close relatives indicate that 80–85% of variation in height is under genetic control with the rest controlled by environmental factors such as diet, nutrition, physical workload, educational attainment and socioeconomic status of the parents, the level of psychological stress, and disease exposure. However, the heritability of height shows significant ontogenetic variation and the strength of the above-mentioned factors is different at subsequent stages of ontogeny. The heritability increases with age. At the moment of birth, the heritability is estimated to be 20–40% and it rises by around 20% during the first year of an infant’s life. In the prepubescent period, the heritability is 60–70% and after puberty it reaches up to 90%. Therefore, adult stature is considered to be informative in terms of health because it is strongly associated with nutritional status at early stages of ontogeny, educational attainment, SES, physical attractiveness of men, mortality, morbidity, and life expectancy.

Body height reaches a peak in the development at the end of the second and at the beginning of the third decade of life and begins to diminish thereafter [2, 4, 10, 13, 23]. Although age-related changes in height after maturity are relatively slow and slight, the rate of reduction depends on a number of different factors. In 1947, Hooton stated that the period of decline commences no later than age 25 [13], which was in agreement with previous studies [2]. Spirduso et al. maintain that the onset of reduction in height is at the age of 25 in men and 20 in women [31]. On the other hand, other researchers found no evidence of significant decline until age 40–45 [1, 7, 8, 21, 32]. Between the ages of 30 and 90, stature decreases by 1.0–2.0 cm/decade, which in total comprises around 5–6% of final adult stature. However, the aging-associated retrograde change in body height of elderly people ranges from 1.0 to 4.0 cm per decade because the rate of reduction tends to accelerate in the consecutive decades of life [30].

It has been demonstrated that middle-age men lose about 1.0 mm per year, whereas middle-aged women lose nearly 1.3 mm per year [7, 8]. Sagiv et al. suggested that the rate of decrease in height with age is higher in women due to the consequences of oestrogen loss during menopause, which have a pernicious effect on health because it is associated with a significant reduction in bone mineral density (BMD), higher prevalence of osteopenia, osteomalacia, and osteoporosis [25]. Between the ages of 30 and 90, the thickness of the cortical bone layer of long bones diminishes by 10% in men and by 20–30% in women. The rate of reduction depends on genetic inheritance, diet and nutrition [26, 27, 31] (particularly important, because of their preventive action, are foods which are high in calcium, e.g. dairy products, tofu, sardines, salmon, seaweed, figs, kale, savoy cabbage, broccoli, white beans, black-eyed peas,
garden cress, turnip greens, almonds, hazelnuts, sesame seeds, etc.). Sagiv et al. determined that between the ages of 35 and 85 physically active men lose nearly $3 \pm 0.5$ cm, while active women lose $3.5 \pm 0.8$ cm of their height. Physically inactive men lose around $5.4 \pm 0.5$ cm, whereas women lose approximately $6.3 \pm 0.6$ cm [25]. The study carried out by van Leer et al. [33] revealed that between ages 40 to 74, a reduction in stature of women ($N=13,386$) amounted to $4.9 \pm 0.3$ cm. In the same period of time, sitting height decreased by $3.9 \pm 0.2$ cm. Taking into consideration some confounding factors, the researchers established that age-related reduction in stature was $3.0$ over 35 years.

It should be stressed, however, that the strength of the connection between the rate of reduction in body height and biological condition of men and women varies among older individuals from different regions of the world [15, 19]. The strength of the relationship depends on initial age of the onset, gender, health, medical care, socioeconomic status, and physical activity [20]. The rate of decrease in height with aging in the subjects from the PLSA is very similar and commensurate with the rate of height loss for other studied populations. Postmenopausal women experience a more rapid loss of height at later stages of ontogeny compared with men, which is in agreement with results of previous studies [12, 23, 29, 30].

By and large, subjects with mobility problems, hypokinesia, and those who led sedentary lifestyle were more likely to develop other negative health-related outcomes which further aggravated the problem of regressive changes in height. Generally, physical inactivity in older people due to sedentary lifestyle, mobility problems, MSDs, hypokinesia or iatrogenic effects of lengthy hospitalization can lead to an increased rate of reduction in their stature. Many epidemiological studies have demonstrated that a rapid loss of height can be a reliable indicator of increased risk of osteoporosis, fractures, falls, physical frailty, and susceptibility to certain aging-associated diseases [5, 9–12, 14, 16, 19, 20, 22, 29, 34]. For example, a large prospective study which followed 4,213 men whose stature was assessed between the ages of 40 and 59 and again 20 years later (i.e. between the ages of 60–79) showed that a rapid loss of height (i.e. $\geq 3$ cm) was independently associated with an increased risk of all-cause as well as cause-specific mortality [34]. Marked rate of loss of height with age and morbidity rate were closely correlated except for risk of cancer and diabetes mellitus. Men who lost above 3 cm were more at risk of CVD, CHD, MSDs, mobility problems, and all-cause mortality than men who lost less height in the period under study.

The rate of height loss higher than 5 cm over 15 years in older women ($N=3,124$) was associated with a substantially increased risk (roughly 50%) of hip fracture, non-vertebral fracture, and mortality, independently of the occurrence of vertebral fractures and reduced BMD. It was earlier demonstrated that middle-aged and older men and women with annual loss of height $>0.5$ cm are at significantly higher risk of osteoporotic fractures and their negative after-effects. Moayyeri et al. determined that the height loss $>2$ cm within four years is a strong predictor of future osteoporotic fractures [19]. The study concluded that serial measurements of height should be recommended as part of a basic geriatric assessment. Unfortunately, such measurements
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are not routinely performed by clinicians caring for older people. Clinicians who evaluate changes with age in height of their patients are able to accurately predict the increased risk of CVD, osteoporosis, and mortality.

CONCLUSIONS

To sum up, aging-associated decline in stature is an ineluctable process which develops even in healthy and physically active individuals. After menopause, older women experience a more rapid decrease in their height. The interrelationship between the higher rate of decline in stature with age and the increased risk of morbidity and mortality depends on certain biological and socioeconomic factors. Patients who experience a substantial loss of height are at higher risks of CVD, osteoporotic fractures, and all-cause mortality. The rate of regressive changes with age in body height can be used as an inexpensive and reliable measure of health status, physical fitness and biological condition of older individuals. Moreover, the rate of loss of height provides useful prognostic information for clinicians caring for older people.

REFERENCES


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ABSTRACT

The relationship between the rate of height loss with age in older people and their health status has been well documented in the medical literature. Our study was aimed at furthering the characterization of this interrelationship in the context of cause-specific and all-cause mortality in the Polish population. Longitudinal data on health profiles and changes with age in adult stature were available from 142 physically healthy inmates at the psychiatric hospital, including 68 men and 74 women, whose health was evaluated for at least 25 years, starting from the age of 45 onwards. Information on causes of death in the Polish population was used in the analysis. ANOVA, t-test, and regression analysis were run. The results revealed that the onset of height loss occurred in the fourth decade of life. There was a gradual acceleration in the rate of reduction at later stages of ontogeny in both sexes. However, postmenopausal women experienced a more rapid height loss compared with men. The subjects who had higher rate of reduction in this trait with age (i.e. HL≥3 cm/decade) were at greater risk of CVD, osteoporotic fractures, and all-cause mortality. The findings suggest that a systematic assessment of the rate of height loss can be useful for clinicians caring for elderly people.

STRESZCZENIE

Związek pomiędzy tempem ubytków wysokości ciała z wiekiem u osób starszych a ich stanem zdrowia został dobrze udokumentowany w literaturze medycznej. Nasze badania miały na celu rozwinięcie charakterystyki tej współzależności w kontekście śmiertelności oraz umieralności w populacji polskiej. W celach porównawczych zgromadzono dane na temat 142 zdrowych pod względem fizycznym pensjonariuszy szpitala psychiatrycznego, w tym 68 mężczyzn i 74 kobiet, badanych w sposób ciągły przez okres co najmniej 25 lat, począwszy od 45. roku ich życia. W analizie uwzględniono informacje dotyczące przyczyn zgonów w populacji polskiej. Analizy statystycznej dokonano przy pomocy ANOVA, testu t Studenta i analizy regresji. Wyniki wykazały, iż początek ubytek w wysokości ciała ujawnił się w czwartej dekadzie życia. W późniejszych etapach ontogenezy obserwowano stopniowe zwiększanie się tempa redukcji wysokości ciała u obu płci. W porównaniu z mężczyznami kobiety w okresie postmenopauzalnym doświadczały większych zmian wstecznych. Badane osoby, które miały wyższe tempo redukcji tej cechy z wiekiem (tj. HL≥3 cm/decade) były także bardziej zagrożone chorobami układu sercowo-naczyniowego, złamaniami na tle osteoporozy, jak również ich ryzyko zgonu z dowolnej przyczyny było wyższe. Przedstawione wyniki sugerują, że systematyczna ocena tempa ubytków wysokości ciała może być przydatna dla klinicystów zajmujących się osobami w podeszłym wieku.

Artykuł zawiera 24587 znaków ze spacjami