The aim of the study was to analyze somatometric chest structure in persons aged over 100 years. The study group included 83 women and 13 men, aged 100-108 yr (median age -100.8 yr), who participated in the scientific project: 'Genetic and Environmental Factors of Longevity of Polish Centenarians' in 2002-2004. The Rohrer index of chest structure using acromion-acromion length and body height were compared with the results of pulse oximetry, spirometry, and the level of general physical activity. The majority of the centenarians had a pyknic structure of the chest, most likely as a result of a progressive reduction of body height and chest stooping. In comparison with the women who had marked alterations of chest structure, females with less profound changes had a lower respiratory rate, better tolerance of exercise, higher forced vital capacity, and a higher physical activity. A small number of male subjects studied made it impossible to analyze statistical correlations in this group. We conclude that there is a need to redefine anthropometric indices for a reliable assessment of chest structure in senescent subjects.

**Key words:** aging, anthropometry, centenarians, longevity, respiratory function

**INTRODUCTION**

Aging of the respiratory system includes anatomic and functional changes in the upper and lower respiratory tract and also a deformation of chest structure (1, 2). Progressive compression of the vertebral column, often associated with fractures of vertebral bodies and scoliosis, affect mechanical properties of the chest and significantly increase the work of breathing (3, 4). The aim of the
present study was to evaluate the chest structure in persons reaching extreme longevity of over 100 years and to assess the relationship between anthropometric chest structure indices and respiratory function in centenarians. In the present work, the term 'centenarians' refers to all studied subjects, irrespectively of their exact age at the time of the examination.

MATERIAL AND METHODS

Subjects

The study conformed to the Declaration of Helsinki and informed written consent was obtained from each subject. The study protocol was approved by the Bioethics Commission of the Military Institute of Health Services in Warsaw.

The study group consisted of 96 subjects, F/M-83/13, aged 100-108 yr. The subjects were visited at their place of living in the framework of a scientific project: 'Genetic and environmental factors of longevity of Polish centenarians', in 2002-2004. The female/male ratio was 6/1 and the median age of the subjects equaled 100.8 yr.

Clinical evaluation

Medical examination was performed, including visual assessment of the chest, acromion-acromion width, and body height and weight. Patients were asked about their body height and weight at the age of 50. Additional tests included the assessment of transcutaneous oxygen hemoglobin saturation (StO₂) and pulse rate using a pulse oximeter Nonin Onyx 9500 (Nonin Medical, Plymouth, USA), performed in the sitting position and after exertion, defined as walking from one room to another. Spirometry was performed using a portable spirometry device attached to an AsCARD B5 electrocardiograph (Aspel SA, Zabierzow, Poland). Additionally, clinical geriatric scales were used to assess mobility of subjects, e.g. the ability to walk.

Anthropometric indices

The following anthropometric indices were used: body mass index (BMI), calculated from body weight and height (kg/m²), body surface area (BSA) at present and at the age of 50, calculated according to the equation: 16.72 x √weight (kg) x √height (cm) (5, 6), and the Rohrer index of chest structure, defined as acromion-acromion width (cm)/height (cm) x 100 (7). Data are expressed as means ±SD. Statistical significance of the data was assessed using one-way ANOVA.

RESULTS

Due to specific challenges related to the advanced age and functional disability, not all of the tests could be performed in all of the centenarians studied. Two thirds of subjects or their caregivers were able to recall the subjects' height at the age of 50 yr and there were sufficient data to calculate the Rohrer index in 53 (64.0%) women and 7 (53.8%) men. Only 25% of the women and 46% of the men studied were able to perform spirometry. Due to the small
number of the men, only the results obtained in the female group were suitable for further statistical analysis.

### Anthropometric indices

The mean BSA of the centenarian women and men amounted to 1.38 m$^2$ and 1.62 m$^2$ respectively, which is below the reference value for the category of smallest BSA, considered as 1.67 m$^2$ (7). A considerable loss of BSA between the age of 50-100 was noted in both sexes: -0.26 m$^2$ for women and -0.27 m$^2$ for men. However, BMI of the centenarians fell within the range of normal values for most women (mean value - 23.7 ±4.6) and men (mean value - 24.4 ±4.5), in spite of obvious signs of malnutrition in some of the subjects. Thus, BMI does not seem to reflect reliably the nutritional status. A low reliability of BMI in centenarians may stem from its extensive dependence on the subject’s height of which changes vary widely in individuals during the lifetime, as shown in Table 1.

Based on the Rohrer index, the centenarian women were divided into two groups: Group I - 36 females with a pyknic type of the chest structure (Rohrer index > 24.55) and Group II - 17 females with non-pyknic chest structure (Rohrer index <24.55). The women with more pyknic chest had a greater loss of height (17.7 cm vs. 13.2 cm; $P=0.026$). There was no significant relationship between the Rohrer index and height at the age of 50 yr. It is worth noting that the value of the Rohrer index correlated well with the visual assessment of chest structure, provided by a physician conducting physical examination of the centenarians. Kyphosis was seen in nearly 80% of Group I and 50% of Group II subjects.

### Table 1. Loss of height in centenarians between the ages of 50 and 100+.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Height-50</th>
<th>Height-100+</th>
<th>Height loss</th>
<th>Maximum height loss</th>
<th>Minimum height loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>159 ±5</td>
<td>143 ±7</td>
<td>16 ±6</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>Male</td>
<td>170 ±5</td>
<td>157 ±11</td>
<td>13 ±9</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

Height is given in cm as means ±SD. Height-50, body height at the age of 50; Height-100+, body height at the age of over 100 at the time of the examination.

### Table 2. Relationship between the chest structure, as based on the Rohrer index (RI), and respiratory rate, transcutaneous hemoglobin saturation, heart rate, and FVC in centenarian women.

<table>
<thead>
<tr>
<th>Respiratory rate (breaths/min)</th>
<th>Pyknic chest RI &lt; 24.55</th>
<th>Non-pyknic chest RI &gt; 24.55</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>StO$_2$ - sitting (%)</td>
<td>22.7</td>
<td>19.4</td>
<td>0.002</td>
</tr>
<tr>
<td>StO$_2$ - exertion (%)</td>
<td>95.7</td>
<td>96.5</td>
<td>NS</td>
</tr>
<tr>
<td>Heart rate - sitting (beats/min)</td>
<td>78.9</td>
<td>73.7</td>
<td>0.047</td>
</tr>
<tr>
<td>Heart rate - exertion (beats/min)</td>
<td>88.1</td>
<td>81.6</td>
<td>NS</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>1.05</td>
<td>1.48</td>
<td>NA</td>
</tr>
</tbody>
</table>

StO$_2$, transcutaneous oxyhemoglobin saturation; FVC, forced vital capacity; NS, nonsignificant; NA, not applicable.
Anthropometric indices and clinical findings

Centenarian women with pyknic and non-pyknic chest structures were compared with respect to other clinical findings and these results are presented in Table 2. The women with pyknic chest had a significantly higher respiratory rate than the non-pyknic ones (22.7 vs. 19.4 breaths/min, respectively; P=0.002). There were no differences in the resting \( \text{StO}_2 \) and pulse rate between the two groups. However, the women with more profound chest structure alterations had a worse tolerance of exercise, as expressed by a significantly lower \( \text{StO}_2 \) on exertion (94.4% vs. 96.1%; P=0.047) and a trend toward a higher pulse rate (88.1/min vs. 81.6/min) in comparison with the non-pyknic women. The non-pyknic chest subjects had higher values of forced vital capacity (1.48 L vs. 1.05 L), but spirometry was successfully performed only by three patients in this group and a reliable statistical confirmation of this relationship is impossible. The subjects with a pyknic chest were less physically fit than those with normal chest structure and required assistance in walking significantly more often than the latter group (52.7% vs. 35.3%, respectively).

DISCUSSION

To the best of our knowledge, this is the first study addressing the issue of anthropometric chest structure in a relatively large group of centenarians. Despite a detailed description of chest structure changes associated with aging (1-4), the available literature does not provide information to what extent chest deformation would affect respiratory function and general health status in extremely old subjects.

Our study demonstrates that BSA decreased considerably between the ages of 50-100 as a result of height loss reaching the maximum value of 31 cm. Since BMI depends strongly on the actual height, it may overestimate the nutritional status of subjects with a substantial loss of height. Thus, BSA might be considered a more reliable indicator than BMI. It must be stressed, however, that the height of subjects at the age of 50 was a self-reported value, which makes it of limited validity.

The loss of height seems to be a key factor leading to structural changes of the chest associated with aging (4). Women with a pyknic chest, as assessed by the Rohrer index, did not differ from those with a non-pyknic chest in terms of height at the age of 50, but the pyknic group had a greater loss of height and lower height at the time of the study. Aging of the thorax increases the work of breathing (2). In the present study, the pyknic chest structure correlated with a higher resting respiratory rate and lower oxyhemoglobin saturation on exertion, being likely caused by changes in respiratory mechanics. Moreover, chest structure abnormalities impaired the ability to walk without caregiver's help. It seems a reasonable assumption that prevention of height loss and chest deformation, for instance through early rehabilitation and prevention of osteoporosis in persons approaching old age, could also serve to preserve respiratory function and a level
of independence of elderly subjects. A limitation of the Rohrer index, as used in the present work is related to the fact that it does not recognize the influence of scoliosis on respiratory function. There is a need to seek for a more exhaustive or comprehensive indicator of chest structure in subjects of advanced old age.

To conclude, a pyknic type of chest structure in centenarians is due to a progressive reduction of body height and kyphosis. More profound alterations of chest structure are associated with lower respiratory function and poorer physical activity in centenarian women.

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REFERENCES