Bone mineral density and its relationship with body composition indices in stroke patients


Abstract. Background. Stroke and osteoporosis with its complications are age-related diseases that mainly affect the elderly. The aim of the study was to determine the bone mineral density (BMD), fat and lean mass and their association in stroke patients. Materials and methods. Eighty-six stroke patients and 86 age- and sex-matched individuals without neurological disorders as a comparison group were examined. BMD, lean and fat mass were determined using dual-energy X-ray absorptiometry. Results. Men and women with stroke had a significantly higher frequency of osteoporosis than the comparison group (14.2 vs. 23.3%; 20.5 vs. 4.4%, respectively). BMD in women with a stroke was lower at the level of all examined areas, in men; differences were registered at the proximal femur and the total body. In men with stroke, significantly lower lean mass index (17.9 ± 1.5 and 19.2 ± 1.8 kg/m²; p < 0.05) and the appendicular lean mass index (7.5 ± 0.4 and 8.5 ± 1.0 kg/m²; p < 0.05) were found, and in women — no significant differences in body composition indices were found, however, the frequency of sarcopenia was significantly higher in both men (28.6 vs. 9.5 %, p < 0.05) and women (15.9 vs. 2.3 %, p < 0.05). In men of both groups, positive correlations between total body BMD and lean mass were registered. The dependence of BMD of different areas on fat and lean mass was obtained in stroke women, in contrast to men, in whom the influence of fat mass on BMD was not found. Conclusion. The stroke leads to changes in bone mineral density and lean (muscle) mass and therefore is a risk factor for the development of osteoporosis and sarcopenia.

Keywords: osteoporosis; bone mineral density; fat mass; lean mass; sarcopenia; stroke

Introduction

Hip fractures are known complications of cerebral stroke, but researches of the connection between these two disabling conditions are ongoing. Currently, it is known that the risk of hip fractures is 1.5–2 times higher among the patients who have undergone cerebral stroke than in the general population [1, 2]. A high frequency of falls has a significant impact on the increased risk of fractures. More than 80% of hip fractures are caused by falls [3]. Among the patients who have had a cerebral stroke, the frequency of falls during the first 6 months of the post-stroke period was 23–50% [4]. The causes of the falls of these patients are diverse: motor, coordination, visual impairments, etc. [5]. Currently, another cause of the falls is identified — stroke-associated sarcopenia, a generalized loss of muscle mass due to many factors caused by a stroke [6].

Furthermore, not only the increase of the frequency of falls explains the high risk of fractures. Stroke and osteoporosis, as the main predictor of hip fractures, are age-related diseases, the pathophysiological mechanisms of which potentially overlap. In patients, who have had a stroke, the risk of osteoporosis is almost 2 times higher, and bone mineral density (BMD) is lower in the general population, moreover its loss rapidly progressing after cerebral stroke [7-9]. However, it is currently unknown whether the changes in bone and muscle tissue are related and are the result of multicomponent changes due to stroke or occur independently.

The purpose of our study was to determine BMD, fat and lean mass and their relationship in subjects who have undergone cerebral stroke.

Materials and methods

Population

The study was conducted in the Department of Clinical Physiology and Pathology of the Musculoskeletal System of the State Institution «D. F. Chebotarev Institute of Gerontology of the National Academy of Sciences of Ukraine» in Kyiv, Ukraine. The purpose of our study was to determine BMD, fat and lean mass and their relationship in subjects who have undergone cerebral stroke.
accordance with the terms of the Helsinki Declaration and with the approval of the Ethics Committee of the above institution (protocol No. 4 dated 03.12.2020).

The study involved 86 patients (main group) who had an ischemic stroke in the carotid basin (44 women and 42 men) with a diagnosis of cerebral stroke confirmed by neuroimaging methods (CT or MRI) with motor impairments of various degrees and duration of the post-stroke period from 2 months to 10 years, including men older than 50 and women in the postmenopausal period. The average duration of the post-stroke period did not differ for males and females and was 1.9 ± 0.3 years and 1.7 ± 0.3 years (p = 0.67), respectively. Among the women, 50.0 % of them had a right-hemisphere stroke, 50.0 % a left-hemisphere stroke. For the men, these indices were 55.0 and 45.0 %, respectively. Males and females also did not differ according to the Barthel index (62.0 ± 14.1 and 58.5 ± 18.4 points (p = 0.33), respectively).

The comparison group consisted of 86 subjects (42 men and 44 women) of appropriate age and anthropometric data without neurological pathology (Table 1).

The study did not include patients with any diseases with a proven effect on bone tissue and people taking any pharmaceutical products with a similar effect, as well as subjects with pronounced spasticity, that would interfere with the performance or analysis of dual-photon X-ray absorptiometry (DXA). A mandatory condition for the inclusion in the study was the presence of voluntary informed consent for participation of the patient.

**Methods**

All included subjects underwent an anthropometric examination. Body weight was measured using medical scales with an accuracy of 0.2 kg on the day of measurement of bone tissue. The height was determined using a height meter with an accuracy of 0.5 cm, the body mass index (BMI) was calculated according to the Quetelet formula: BMI = body weight / height of the patient squared. The assessment of the functional state of the patients who have had cerebral stroke was performed according to the Barthel Index (Barthel Activities of Daily Living (ADL) Index) [10].

Bone mineral density was determined using dual-photon X-ray absorptiometry (DXA) using “Prodigy, GENS Lunar”, Madison, USA, 2005. The DXA method examined the following areas of the skeleton: lumbar (L₁-L₄) spine, proximal part of the femur (hip), femoral neck, the distal part of the forearm and the total body. As a result of carrying out of DXA, there were determined BMD (g/cm²), T-index (difference in BMD of a separate part of the patient’s skeleton from the index of conditionally healthy adults aged 20 years, reflected in root mean square deviations); Z-index (the difference in BMD of a separate area of the patient’s skeleton from the index of conditionally healthy adults of the same age, reflected in root mean square deviations). Assessment of BMD in postmenopausal women and men at the age of 50 years and older was performed according to WHO criteria based on the value of the T-index at the level of lumbar (L₁-L₄) spine, hip or femoral neck (the lowest index). The value of T-index < -2.5 corresponds to osteoporosis, between > -2.5 and < -1 – low BMD (osteopenia), > -1 corresponds to normal BMD [11].

Assessment of body composition (fat, lean mass) was also carried out using DXA. The fat and lean mass of the total body and its parts (kg) were assessed, the fat mass index was calculated (fat mass/height²), FMI, kg/m²), lean mass index (fat mass/height², LMI, kg/m²), appendicular lean mass (lean mass of limbs) and appendicular lean mass index (lean mass of limbs/height², ALMI, kg/m²) [12].

Statistical analysis was performed using the Statistica 10 and MEDCALC® programs (Internet resource with open access, https://www.medcalc.org/calc). Descriptive statistics methods were used with definition of M – sample mean, SD – sample standard deviation. The normality of the distribution was determined by the Shapiro-Wilk test. Differences in the indices between groups were established using the Student’s t test for independent samples. Correlation analysis was performed using Pearson’s correlation in the case of parametric and Spearman’s correlation in the case of non-parametric distribution of data. Differences in the distribution of samples were assessed using the χ² test. The results are presented as mean values and their standard deviation (M ± SD). Differences between the indices were considered significant at p < 0.05.

**Results**

BMD indices in women who have had cerebral stroke were significantly lower compared to the indices of the comparison group in all examined areas: the total body, hip, femoral neck, and distal part of the forearm (Table 2).

In contrast to the above, BMD in men at the lumbar (L₁-L₄) spine and femoral neck did not differ from the indices of the comparison group, however, at the hip

<table>
<thead>
<tr>
<th>Indices</th>
<th>Comparison group</th>
<th>Patients with cerebral stroke</th>
<th>p₁</th>
<th>p₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>men (n=42)</td>
<td>women (n=44)</td>
<td>men (n=42)</td>
<td>women (n=44)</td>
</tr>
<tr>
<td>Age, years</td>
<td>64.5 ± 8.9</td>
<td>65.1 ± 9.1</td>
<td>64.8 ± 8.6</td>
<td>65.2 ± 8.7</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.74 ± 0.06</td>
<td>1.60 ± 0.06</td>
<td>1.74 ± 0.06</td>
<td>1.61 ± 0.06</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>84.2 ± 12.8</td>
<td>77.2 ± 15.8</td>
<td>85.2 ± 13.5</td>
<td>81.2 ± 13.0</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27.9 ± 4.7</td>
<td>29.8 ± 5.5</td>
<td>28.0 ± 4.1</td>
<td>30.8 ± 5.2</td>
</tr>
</tbody>
</table>

Notes. Data are presented as M ± SD, p₁ – differences between the indices of men of two groups, p₂ – differences between the indices of women of two groups. The significance of the differences was determined using the Student’s test for the independent samples.

(1.041 ± 0.165 and 1.093 ± 0.076 g/cm², p = 0.04) and total body (1.213 ± 0.113 and 1.260 ± 0.079 g/cm², p = 0.02) were significantly lower.

Differences of BMD in women were 11.3 % at the lumbar (L₁-L₄) spine, 18.3 % at the femoral neck, and 20.0 % at the hip. Among the men, differences at the hip are 4.9 %, and the total body – 3.8 %. Such differences may be caused by the sexual characteristics of bone tissue and the vascular system.

The frequency of osteoporosis in the patients who underwent cerebral stroke was significantly higher than in the comparison group, as in men (14.2 and 2.3 %, χ² = 3.9, 95 % (CI): 1.5 – 25.6; p < 0.05), as well as in women (20.5 and 4.5 %, χ² = 5.1; CI: 1.9 – 30.4, p < 0.05, respectively). Therefore, cerebral stroke is a risk factor for the development of osteoporosis, more pronounced among women.

Body composition assessment of men who have had cerebral stroke revealed significantly lower values of lean mass (54.3 ± 7.7 and 57.8 ± 6.4 kg; p < 0.05) and appendicular lean mass (22.8 ± 3.8 and 25.5 ± 3.5 kg, p < 0.05) than among the persons of the comparison group. However, the fat mass in both groups did not differ significantly (26.6 ± 9.9 and 25.2 ± 8.3 kg; p > 0.05).

No significant differences in body composition parameters were registered in women. The indices of fat mass did not differ both in percentages (42.5 ± 6.6 and 43.8 ± 4.6%; p < 0.05) and in absolute numbers (33.4 ± 12.8 and 33.7 ± 9.2 kg; p < 0.05). Differences between lean (42.6 ± 6.6 and 43.9 ± 5.6 kg; p > 0.05) and appendicular lean mass indices (17.3 ± 2.9 and 18.0 ± 2.1 kg; p > 0.05) were also not significant.

Sarcopenia according to the appendicular lean mass index (ALMI < 7.2 kg/m²) in men of the main group was recorded significantly more often than in the comparison group, in 28.6 and 9.5 %, respectively, χ² = 4.9 (CI 2.15–35.16), p = 0.03. Sarcopenia (ALMI less than 5.45 kg/m²) was observed in 15.9 % of women in the main group and only in 1 woman (2.3 %) in the comparison group (χ² = 4.86 (CI 1.15–27.19), p = 0.03).

Among the men of the main group significantly lower indices of LMI, ALM and ALMI were also established, among the women similar differences were not found (Table 3).

Lean mass indices were significantly lower in the men who have had cerebral stroke, and no differences in body composition parameters were reported among the women. BMD, on the contrary, was significantly lower among the females at the all examined areas, and among the men at the hip and the total body, and the differences in BMD indices from the data of the comparison group in men were significantly lower. Therefore, according to our data BMD mainly decreases in women, and lean mass – in men, in the absence of gender differences in the duration of the post-stroke period or functional deficits (according to the Barthel index).

The correlation analysis of the indices in men of both groups revealed reliable positive moderate relationship strength between total body BMD and the indices of lean mass. No relationship between BMD and fat tissue indices was found in men of both groups. In males, there were no correlations between BMD of the lumbar (L₁-L₄) spine, the hip or femoral neck with body composition indices.

Among the women of the comparison group, positive moderate correlations were established between the total body BMD with the indices of lean mass, and also, unlike men, with indices of fat mass. In women with cerebral stroke the dependence of BMD indices of different localization on fat and lean mass was obtained (Table 4).

Therefore, in patients who have had cerebral stroke, sarcopenia (according to the ALMI) was established reliably more often in both men and women, although significant differences in lean mass indices were recorded only in men.

In men, no correlations were obtained between BMD and the Barthel index, and in women, significant moderate positive correlations were found between the Barthel index

**Table 2. Bone mineral density indices in women who have had cerebral stroke and the subjects in the comparison group**

<table>
<thead>
<tr>
<th>Indices</th>
<th>Comparison group</th>
<th>Women after cerebral stroke</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD of LS, g/cm²</td>
<td>1.07 ± 0.20</td>
<td>1.19 ± 0.18</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>T-score of LS, SD</td>
<td>–1.1 ± 1.6</td>
<td>0.1 ± 1.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Z-score of LS SD</td>
<td>0.1 ± 1.4</td>
<td>1.0 ± 1.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>BMD of FN, g/cm²</td>
<td>0.84 ± 0.14</td>
<td>0.99 ± 0.10</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>T-score of FN, SD</td>
<td>–1.4 ± 1.0</td>
<td>–0.3 ± 0.7</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Z-score of FN, SD</td>
<td>–0.2 ± 0.6</td>
<td>0.9 ± 0.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>BMD of the hip, g/cm²</td>
<td>0.90 ± 0.16</td>
<td>1.08 ± 0.12</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>T-score of the hip, SD</td>
<td>–0.8 ± 1.2</td>
<td>0.6 ± 0.9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Z-score of the hip, SD</td>
<td>0.2 ± 0.9</td>
<td>1.4 ± 0.9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>BMD of TB, g/cm²</td>
<td>1.07 ± 0.12</td>
<td>1.18 ± 0.09</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>T-score of TB, SD</td>
<td>–0.7 ± 1.6</td>
<td>0.7 ± 1.2</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Z-score of TB, SD</td>
<td>–0.1 ± 1.0</td>
<td>1.2 ± 1.0</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Notes.** Data that are presented as M ± SD. BMD – bone mineral density, LS – lumbar spine, FN – femoral neck, TB – total body, p – differences between the indices of the patients of the main and the comparison groups. The significance of the differences was determined using the Student’s test for independent samples.

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and BMD of lumbar (L2-L4) spine \((r = 0.42, p < 0.05)\), femoral neck \((r = 0.40, p < 0.05)\), hip \((r = 0.40, p < 0.05)\) and total body \((r = 0.42, p < 0.05)\).

We did not find a correlation between the Barthel index and body composition indices in men who have had cerebral stroke, and in women a positive correlation \((r = 0.30)\) was established between LMI and the Barthel index, while there was no such correlation discovered between LMI. In our study, the effect of the post-stroke duration on BMD indices of the axial skeleton or body composition in both women and men was not established. Therefore, cerebral stroke is a risk factor for the development of sarcopenia, more pronounced in men.

**Discussion**

The connection between stroke and fractures is a problem that has been studied for more than a decade. The appearance of the possibility of quantitative assessment of BMD introduced an intermediate link in this chain – osteoporosis. However, there are significantly more predictors of fractures in patients who have had cerebral stroke than in subjects without neurological and cardiac pathology, and therefore it is currently impossible to explain the high risk of fractures only by changes in BMD. No direct correlation between the severity of neurological deficits and fractures was found, on the contrary, patients with mild neurological deficits have the highest risk of fractures, which is due to greater activity and, therefore, a greater risk of falls [13]. However, determining of BMD and its correcting if necessary is an effective and promising way to reduce the risk of fractures. Among the patients who have had cerebral stroke, the BMD differences in women were demonstrated in all examined areas, and in men only at the hip and total body.

In literary data, lower BMD indices were also obtained, but the degree of differences fluctuates significantly [3, 14], which, in our opinion, is conditioned by the heterogeneity of the examinees. Within a year after a stroke, bone loss at the paretic limbs increases to 12-17 % [15], which significantly exceeds the age-related loss and therefore increases the fractures risk.

A study of body composition of the men who have had cerebral stroke revealed significantly lower lean body mass index with an increased incidence of stroke-associated sarcopenia – 28.6 % versus 9.5 % in the comparison group. In women, the frequency of sarcopenia was also higher (15.9 and 2.3 %, respectively), although no significant differences in body composition were found. Perhaps, in women, such changes are expressed to a lesser extent, which is conditioned to a lower percentage of lean tissue in the body composition in comparison to men. In the literary sources, patients were not divided by gender, and the frequency of sarcopenia was reported to be 14-18 %, in our study the frequency of sarcopenia was 22.1 %, but the duration of the post-stroke period and the age of the patients in our study were higher [6].

On the other hand, fat mass is more pronounced in women. As is known, a decrease in fat mass among women is associated with an increase of the fractures risk, however, according to new studies, obesity, especially of the android type, independently increases the risk of both – cerebral stroke and fractures [16, 17]. In our study, there were no differences in body fat mass or body fat mass index in either men or women. Probably, the lack of differences is conditioned by the standardization of patients by body weight.

The separate influence of fat and lean mass on BMD indices in conditions of various nosologies is currently being actively studied, most researchers are inclined to the fact

### Table 3. Body composition indices in men and women who have had cerebral stroke and subjects of the comparison group

<table>
<thead>
<tr>
<th>Indices</th>
<th>Comparison group</th>
<th>Patients with cerebral stroke</th>
<th>(p_1)</th>
<th>(p_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>men</td>
<td>women</td>
<td>men</td>
<td>women</td>
</tr>
<tr>
<td>ALM, kg</td>
<td>22.9 ± 2.7</td>
<td>17.8 ± 2.7</td>
<td>25.6 ± 3.3</td>
<td>17.7 ± 1.9</td>
</tr>
<tr>
<td>FMI, kg/m²</td>
<td>8.8 ± 2.7</td>
<td>12.8 ± 4.5</td>
<td>8.4 ± 2.4</td>
<td>12.9 ± 2.7</td>
</tr>
<tr>
<td>LMI, kg/m²</td>
<td>17.9 ± 1.5</td>
<td>16.6 ± 2.2</td>
<td>19.2 ± 1.8</td>
<td>16.3 ± 1.5</td>
</tr>
<tr>
<td>ALMI, kg/m²</td>
<td>7.5 ± 0.4</td>
<td>6.7 ± 0.9</td>
<td>8.5 ± 1.0</td>
<td>6.8 ± 0.4</td>
</tr>
</tbody>
</table>

Notes. Data are presented as \(M ± SD\), ALM – appendicular lean mass, FMI – fat mass index, LMI – lean mass index, ALMI – appendicular lean mass index, \(p_1\) – differences between indices of men of two groups, \(p_2\) – differences between indices of women of two groups. Comparison was performed using Student’s t test for unrelated samples.

### Table 4. Correlations between body composition indices and BMD of different parts of the skeleton in women who have had cerebral stroke and women from the comparison group

<table>
<thead>
<tr>
<th>Indices</th>
<th>Females of comparison group</th>
<th>Women after cerebral stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fat mass, g</td>
<td>lean mass, g</td>
</tr>
<tr>
<td>BMD of LS, g/cm²</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>BMD of FN, g/cm²</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>BMD of the hip, g/cm²</td>
<td>0.19</td>
<td>0.10</td>
</tr>
<tr>
<td>BMD of TB, g/cm²</td>
<td>0.47*</td>
<td>0.39*</td>
</tr>
</tbody>
</table>

Notes. The data are presented as Pearson’s correlation coefficient, BMD – bone mineral density, LS – the lumbar spine, FN – femoral neck, TB – the total body. * – \(p < 0.05\).
that muscle tissue has the predominant influence on bone tissue.

According to the data of the literature, for women in the postmenopausal period, a correlation between a decrease in lean body mass and an increase in the risk of fractures was found, regardless of BMD [18]. In our study, there were no differences in lean body mass between women of the control group and women with cerebral stroke, but a significant relationship between femoral BMD and lean body mass index was reported, which may cause the indirect effect of lean body mass on the risk of fractures.

So, in women who have had cerebral stroke, there are significant relationships between BMD, fat and lean mass, and connections between BMD of different localization, LMI and functional deficits (according to the Barthel index), and in men there are no such relationships. However, a decrease in lean body mass and a higher frequency of sarcopenia were registered in men, in the absence of gender differences in the duration of the post-stroke period and the severity of the disease. The revealed differences in BMD, body composition and their correlations in men and women who have had cerebral stroke require further research with an emphasis on gender peculiarities.

**Limitations of this study:** its design (case-control and single-center), heterogeneity of the examined subjects (various degrees of the neurological deficit), small number of the involved patients (86 people who have had cerebral stroke), which did not allow to clearly distinguish specific changes or to reveal the dependence of certain factors.

**Conclusions**

The results of the study indicate that stroke leads to the changes in bone mineral density and lean (muscle) mass, and therefore is a risk factor for the development of osteoporosis and sarcopenia, which, when combined, significantly increase the risk of fractures.

**References**


Бистрицька М.А.
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Мінеральна щільність кісткової тканини та її зв’язок з показниками тілобудови у пацієнтів, які перенесли мозковий інсульт

Резюме. Актуальність. Мозковий інсульт (МІ) та остеопорозу з його ускладненнями — віксоційовані захворювання, які вражають переважно осіб літнього віку. Метою дослідження було визначити показники мінеральної щільності кісткової тканини (МЩКТ), жирової й знежиреної маси та їхній зв’язок в осіб, які перенесли МІ. Матеріали та методи. Було обстежено 86 пацієнтів, які перенесли МІ, та 86 осіб відповідного віку та статі без неврологічної патології, які становили групу порівняння. МЩКТ, показники знежиреної та жирової маси визначали за допомогою двофотонної рентгенівської абсорбціометрії. Результати. У чоловіків і жінок, які перенесли МІ, частота остеопорозу була вірогідно вищою, ніж в осіб звичайної порівняння (14,2 та 2,3 %; р < 0,05), у жінок вірогідних відмінностей показників тілобудови не виявлено, проте частота саркопенії була вірогідно вищою як у чоловіків (28,6 та 9,5 %; р < 0,05), так і в жінок (15,9 та 2,3 %; р < 0,05). У чоловіків обох груп виявлено вірогідні позитивні зв’язки між МЩКТ усього скелета та показниками знежиреної маси. У жінок із МІ отримано залежність показників МЩКТ різної локалізації від звичайної та знежиреної маси на відміну від чоловіків, у яких вплив жирової маси на показники кісткової тканини не знайдено. Висновки. Мозковий інсульт призводить до змін МЩКТ й знежиреної (м’язової) маси, а отже, є фактором ризику розвитку остеопорозу та саркопенії. Ключові слова: остеопороз; мінеральна щільність кісткової тканини; жирова маса; знежирена маса; саркопенія; мозковий інсульт