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Effects of Anthropometric Factors on Human Cerebellum Weight and Its Developmental Dynamics

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The aim of the present work was to study the relationship between cerebellum weight and its developmental dynamics on the one hand and body length and type of physique on the other. Studies involved 295 corpses of both genders (173 men and 122 women) dying at age 20–99 years. Body length was measured, along with the cross-sectional diameter of the thoracic cage and cerebellum weight. Somatotypes were identified using the Rice-Eysenck index. Human cerebellum weight from was found to vary over the range 103–197 g (mean 144 ± 1.0 g) and was significantly greater in men than women (150.5 ± 1.3 g and 133.9 ± 1.2 g, $p < 0.001$). Age had a greater influence on cerebellar weight in men than in women ($R = -0.46$ and -0.43, respectively). In men, the period of relatively stable cerebellar weight lasted to about 50 years of age, which was followed by a period of decreasing cerebellar weight. In women, the stable period lasted to about 70 years. Cerebellar weight was related to body length ($R = 0.35$ for men and $R = 0.36$ for women). The relationship between cerebellum weight and body length in men (1.0 g/cm) was greater than that in women (0.5 g/cm): the differences in cerebellum weights in men and women increased with increases in body length. Differences in cerebellum weight in people with different types of physique were minor.

Keywords: cerebellum, body length, type of physique, age.

One area of current study in morphology is that of the patterns of individual anatomical variation [4], and this field has opened up because of in vivo diagnosis of the state of the organs, including the brain, by computer and magnetic resonance tomography [2, 5].

The cerebellum is the most important center for balance and motor coordination – both voluntary and involuntary – at the planning and execution stages [7]. Its size shows gender differences and depends on age [6, 7, 9–15] and the intensity of functional loading [13]. The influences of anthropometric factors on it have received little study [3]; in particular, there have been no studies of the influences of these factors on the developmental dynamics of cerebellum size. The aim of the present work was to study cerebellum weight and its developmental dynamics in relation to body weight and type of physique.

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Materials and Methods

Studies were performed at the Kharkov District Forensic Medical Office using 295 cadavers of people of both genders (173 men and 122 women) who had died at age 20–99 years from causes not involving brain pathology. Somatometric data were collected and cerebellum weight was determined during forensic post mortems. Somatometric parameters were assessed using a metrologically verified toolkit (a growth ruler and pelvis calipers). Body length and the cross-sectional diameter of the thoracic cage were measured using standard forensic medicine methods.

Somatotypes were determined in terms of the Rice-Eysenck index (REI) (body length × 100/cross-sectional diameter of the thoracic cage × 6). In men, physique type was defined as hypersthenic when REI was less than 96.2, normosthenic for the range 96.2–104.8, and asthenic at greater than 104.8. In women, the hypersthenic body type was identified at REI <95.9, the normosthenic at 95.9–104.3, and asthenic at >104.3. Among the men in the study cohort, 69 (40%) had hypersthenic physique, 60 (35%) were normosthenic, and 44 (25%) were asthenic; the corresponding numbers among women were 58 (48%), 29 (24%), and 35 (29%).

Cerebellum weight was determined after removal from the cranial cavity, sectioning of the peduncles, and separation from the brainstem by weighing on a CB-H electronic balance (measurement limit 500 g, accuracy 0.01 g). Changes in cerebellum weight per cm of body length were calculated.

Cohort data were assessed statistically on Microsoft Excel. Mean values ($\bar{x}$) and errors ($s_{\bar{x}}$) were calculated for parameters, which were presented statistically as ($\bar{x} \pm s_{\bar{x}}$); distributions of relative mean values were assessed using the mean square deviation (S), coefficient of variation (CV), the maximum and minimum values, and the interval. Significant differences were identified using Student's test. The strengths of interactions between study parameters were evaluated in terms of the correlation coefficient, R. Plots were constructed and equations for relationships were determined, whose accuracies were evaluated in terms of the approximation coefficient, R^2.

Results

Mean human cerebellum weight was 144.0 ± 1.0 g (range 103–197 g). The mean cohort cerebellum weight in men (150.5 ± 1.3 g) was significantly greater than that in women (133.9 ± 1.2 g, $p < 0.001$). Differences in cerebellar weights in men and women were related to constitutional features of male and female bodies, particularly differences in the somatometric parameters studied: body length (171.3 ± 0.6 cm in men and 158.2 ± 0.3 cm in women, $p < 0.001$), thoracic cage width (29.20 ± 0.20 cm in men and 27.3 cm in women, $p < 0.001$).

Age influenced cerebellum weight in men somewhat more strongly (R = –0.46) than in women (R = –0.43). Different dynamics were seen for changes with age. Cerebellum weight in men in age groups from 21 to 50 years was essentially identical; cerebellum weight in men aged 51–60 years was 94.3% of mean at age 21–50 years, while that at 61–70 years was 91.3%, that at 71–80 years was 87.8%, and that at greater than 80 years was 85.2% ($p < 0.001$) (Fig. 1). In women, cerebellum weight was essentially identical in age groups from 21 to 70 years; that in women aged 71–80 years was 94.7% of the mean for age 20–70 years, that in women of 81–90 years was 88.6%, and that in women of greater than 90 years was 87.3% ($p < 0.01$) (see Fig. 1).

Thus, mean cerebellum weight in elderly men (156.5 ± ± 2.1 g) was 91.5% ($p < 0.01$) and that in old men (143.2 ± ± 3.5 g) was 88.3% ($p < 0.01$) of the mean adult weight (156.5 ± 1.4 g); cerebellum weight in elderly women (139.90 ± 1.9 g), old women (126.9 ± 1.5 g), and very old women (124 ± 4 g) was 96.4%, 88%, and 85.7%, respectively, of adult weight (144.2 ± 2.2 g) ($p < 0.001$).

Body length also showed an overall correlation with cerebellum weight (R = 0.35 for men, R = 0.36 for women). In turn, body length and age were tightly linked by a quite strong negative correlational relationship, this being rather stronger in women (R = –0.42) than men (R = –0.30). Thus, the greater the mean body length in the study group, the lower the mean age and the greater the proportion of people of younger ages. With the aim of minimizing the effects of age, the interaction between body length and cerebellum weight was analyzed in men in the adult group and the group including both elderly and old subjects and between women in the adult and elderly group and the old and very old group (Fig. 2).

Plots of the relationship between cerebellum weight and body length (see Fig. 2) were segments of parabolas and could be described by equations of the $R^2 = 1$ type in men of the first group ($y = –0.004x^2 + 1.734x – 22.884$), the second group ($y = –0.0028x^2 + 1.9294x – 102.52$), in women of the first group ($y = –0.0078x^2 + 2.7556x – 101.46$), and women of the second group ($y = –0.0021x^2 + 1.1055x + 5.7868$).

Cerebellum weight in men was greater than that in women, not only in terms of the mean, but also for identical ranges of bogy length. The nature of the plots (intersection at a sharp angle) indicates that the difference between cerebellum weights in men and women increased with increases in body length (see Fig. 2).

The plots of the relationship between cerebellum weight and body length in different age groups presented in Fig. 2 are not parallel, to a greater extent in men than women: the slope to the x axis, i.e., the dependence of cerebellum weight on body length, increased. The strength of the correlational relationship between cerebellum weight and body length (R = 0.2 and 0.3 in men and 0.1 and 0.3 in women) also increased. This points to different age dynamics for cerebellar size in people with different body lengths. This suggestion was tested by analysis of cerebellar weight in three ranges of body length: short (152–166 cm), intermediate (for all three age groups – adult, elderly, old – combined) (167–179 cm), and long (for the elderly and old groups combined) (180–193 cm).

The difference between values in the adult (153 ± 2.8 g) and elderly (137 ± 3.5 g) people in the first group was about 10% and was statistically significant ($p < 0.05$); the difference between values in elderly and old (133 ± 5 g) people was about 3%, and the overall difference between values in the elderly and old people in this group was 13% ($p < 0.05$).

In the second group, the difference in values in adult (156.4 ± 2.0 g) and elderly (145 ± 3 g) people was 8.5% and was statistically significant ($p = 0.05$); the difference between values in elderly and old (140 ± 5 g) people was about 3%; the total difference between values in adult and old people in this group was just over 10% ($p < 0.05$).

In the third group, the difference between values in adult (160.7 ± 3.0 g) and elderly (154.3 ± 3.2 g) people was 4.0% and was not statistically significant.

In women, cerebellum weight was evaluated in three body length ranges – short (150–155 cm), intermediate (156–161 cm), and long (162–167 cm) for all three age groups (adult, elderly, and old) combined. The differences between weights in the three age groups for all three body length

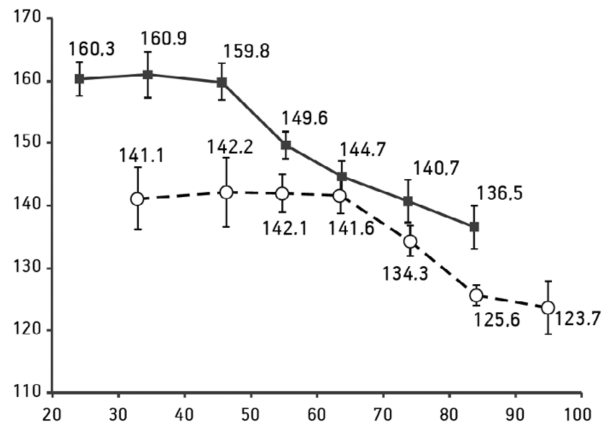

Fig. 1. Developmental dynamics of cerebellum weight in men (continuous line) and women (dashed line) ($\bar{x} \pm s_{\bar{x}}$); the abscissa shows age (years), and the ordinate shows cerebellum weight (g). Vertical bars show errors of the mean.

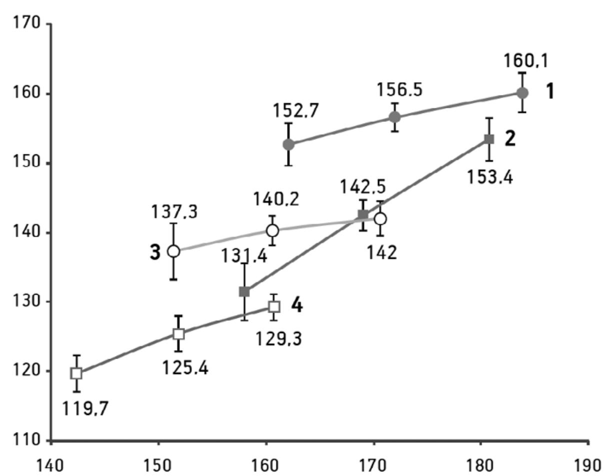

Fig. 2. Relationship between cerebellum weight and body length in men and women of different age groups. Line 1 shows adult men; line 2 shows elderly and old women; line 3 shows adult and elderly women; line 4 shows old women. The abscissa shows body length (cm) and the ordinate shows cerebellum weight (g). Vertical bars show errors of the mean.

ranges were essentially identical: very small (less than 2%) and statistically insignificant between adult (137 ± 3, 140 ± 5, and 143 ± 5 g, respectively) and elderly subjects (136 ± 4, 139.8 ± 2.6, and 140 ± 4 g, respectively) and a little less than 10% ($p < 0.05$) between elderly and old people (127 ± 4, 130.0 ± 1.9, and 125 ± 5 g, respectively).

A further somatometric characteristic influencing the sizes of internal organs is the somatotype. The ratio of cerebellum weight in adult men and women with different physique types was studied in body length ranges for all three physique types combined (162–193 cm for men and 150–174 cm for women), divided into three groups with short, intermediate, and long body lengths in men and two groups in women (see Table 1).

As shown by the data presented in Table 1, cerebellum weight in people of the hypersthenic type of physique was rather greater than in normosthenic and asthenic individuals, though the differences were not statistically significant. In men, the differences in values between neighboring somatotypes was ±3.0%, which was smaller than the coefficient of variation (10%) for each somatotype. In women, measures for the normosthenic and asthenic physique types in both body length ranges were close (difference 1%), while that for hypersthenic individuals was rather greater (difference 4%).

Both men and women with different physique types showed the same type of relationship between cerebellum weight and body length. In adults, increases in body length were accompanied by increases in cerebellum weight by 0.72 g/cm in hypersthenic men, 0.78 g/cm in normosthenic men, and 0.67 g/cm in asthenic men (mean 0.7 g/cm). In adult and elderly women, of the hypersthenic physique type, the relationship between cerebellum weight and body length was 0.6 g/cm, compared with 0.5 g/cm in the normosthenic and asthenic physique types (mean 0.5 g/cm).

With age, the relationship between cerebellum weight and age increased independently of somatotype. In the group consisting of elderly and old men, the increase in cerebellum weight with increases in body length was 0.84 g/cm in hypersthenic men, compared with 1.1 g/cm in those with normosthenic and asthenic physique (mean 1.0 g/cm). In the group consisting of old and very old subjects, the increase in cerebellum weight as body length increased was 0.6 g/cm in hypersthenic women, compared with 0.6 g/cm in those with normosthenic and asthenic physique (mean 0.5 g/cm).

Figure 3 shows cerebellum weight in men and women in groups with different physique and different age groups – three groups in men (adult, elderly, and old) and two in women (one combining adult and elderly women and one consisting of old and very old women). Mean body length in men and women were the same in each age group regardless of somatotype. As shown in Table 3, *a*, there was an age-related decrease in cerebellum weight in hypersthenic men to 94% in the elderly group and 92.5% in the old group, compared with decreases to 93% and 85% in normosthenic men and 92% and 84% in asthenic men. This produced changes in the ratio of cerebellum weight in men of hypersthenic, normosthenic, and asthenic types of physique – from (100–99–96%) at adult age to (100–98–94%) in the elderly and (100–92–87%) in the old.

Cerebellum weight decreased with age to 94% in hypersthenic women, to 93% in normosthenic women, and 89% in asthenic women. This changed the ratio of cerebellum weight in hypersthenic, normosthenic, and asthenic women – from 100–98–97% at adult and elderly age to 100–96–92% in old and very old women (see Fig. 3, *b*). The difference between values in hypersthenic and asthenic types of physique was significant.

TABLE 1. Cerebellum Weight in Adult Men and Women with Different Types of Physique in Groups with Different Body Lengths ($\bar{x} \pm s_{\bar{x}}$)

Type of physique	Body length in men, cm			Body length in women, cm	
	162–171	172–179	180–193	150–162	163–174
Hypersthenic	155 ± 3	158 ± 4	164 ± 6	142 ± 4	148 ± 4
Normosthenic	150.5 ± 2,8	154 ± 3	160 ± 4	137 ± 4	141 ± 4
Asthenic	146 ± 4	150 ± 4	157.7 ± 2.9	135 ± 4	140 ± 3

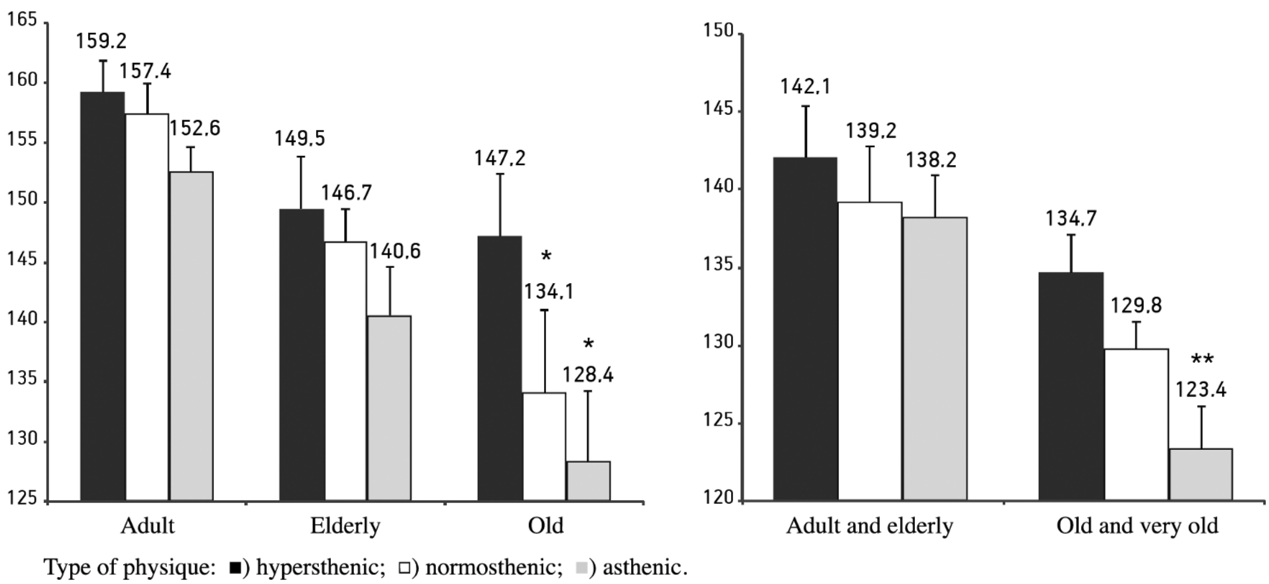

Fig. 3. Cerebellum weight in men (*a*) and women (*b*) in groups with different types of physique at different age periods. The abscissas show age groups and the ordinates show cerebellum weight (g). Vertical bars show errors of the mean. *Significant differences compared with values in men with the hypersthenic type of physique. **Significant differences compared with women with the hypersthenic type of physique.

Discussion

The weight of an organ is an integral measure reflecting its individual variability [4]. The individual anatomical variability of the cerebellum is also based on factors such as gender, age, level of functional loading, and level of completion of motor functions [9, 10, 12, 14, 15].

Many published sources indicate that age is associated with decreases in cerebellum weight. Thus, the classical text of Blinkov and Glezer [1], summarizing advances in neuromorphology leading up to its publication, indicates that cerebellum weight decreases after 50 years of age, this change occurring more or less identically in men and women. Other authors have also relied on these data [9]. The results of these studies provided evidence that in men, the period during which cerebellum weight is relatively stable lasts to about 50 years of age and is then replaced by a period of decline: rapid in the sixth decade of life (by 6.7% of its mean at age 20–50 years) and more slowly at older ages (by 3.7%, 2.5%, and 2.6% in the last decades). In women, the dynamics of age-related changes in cerebellum weight were different. A stable period was seen to age about 70 years. Weight decreased during the eighth decade of life by 3.9% of its value at age 20–70 years, and by a further 6.1% in the ninth decade. In very old subjects, cerebellum weight was 1.3% smaller than at age 80 years, so stabilization of the age-related dynamics of weight appears to occur in very old women.

Body length and somatotype are largely responsible for determining the sizes of the internal organs [8]. The cerebellum controls the somatic musculature [7]; the greater the muscle mass, the greater the incoming loading, so it is not surprising that cerebellum weight also depends on body length and type of physique, which reflect the size of the soma. Study results show that cerebellum size is proportional to body length in both men and women, though this relationship is considerably more marked in men than in women. It may be that this is associated with the fact that relative cerebellum size in women (relative to total brain weight) is initially greater than in men [13]. Differences in cerebellum weight in men and women with different physiques were minor. Body length did not affect this ratio, as cerebellum weights were similar in men and women of the hypersthenic, normosthenic, and asthenic physiques in different body length ranges. In turn, somatotype did not influence the relationship between cerebellum weight and body length, as the increases in cerebellum weight per unit body length were essentially identical in men with different physiques and in women with different physiques.

The experimental results indicate that body length influences the age-related decrease in cerebellum weight in men: the greater body length, the smaller the reduction in cerebellum weight. As a result, the relationship between body length and cerebellum weight becomes greater with age. In women, this same age-related decrease in cerebellum weight was not dependent on body length and the increases in cerebellum weight with increases in body length are identical at different ages.

The somatotype, like body length, affects the age-related dynamics of cerebellum weight, albeit more weakly: in people with hypersthenic physique, the age-related decline in cerebellum weight was smaller than in people with the normosthenic and asthenic types of physique. The result is an alteration in the ratio of cerebellum weight in men and women with different types of physique – it increases with age.

The authors of many published sources have reported that absolute measures of cerebellum weight are smaller in women than men [10–12, 14, 15]. The experimental results show that this ratio is dynamic and depends on age and body length.

Thus, cerebellum weight depends on body length in both men and women. With age, this relationship becomes greater in men but remains unaltered in women. Body length influences the age-related decrease in cerebellum weight in men but has no effect in women.

Cerebellum weight in men and women with the hypersthenic type of physique was greater and age-related changes were less marked than in men and women with the normosthenic and asthenic types of physique.

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