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Fat distribution in children and adolescents with myelomeningocele

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Abstract

AIM—To evaluate quantitatively fat distribution in children and adolescents with myelomeningocele using dual-energy X-ray absorptiometry (DXA).

METHOD—Cross-sectional DXA measurements of the percentage of fat in the trunk, arms, legs, and whole body were compared between 82 children with myelomeningocele (45 males, 37 females; mean age 9y 8mo, SD 2y 7mo; 22 sacral, 13 low lumbar, 47 mid lumbar and above) and 119 comparison children (65 males, 54 females; mean age 10y 4mo, SD 2y 4mo). Differences in fat distribution between groups were evaluated using univariate and multivariate analyses.

RESULTS—Children with myelomeningocele had higher total body fat (34% vs 31%, p=0.02) and leg fat (42% vs 35%, p<0.001than comparison children, but no differences in trunk or arm fat after adjustment for anthropometric measures.

INTERPRETATION—Children with myelomeningocele have higher than normal total body and leg fat, but only children with higher level lesions have increased trunk fat, which may be caused by greater obesity in this group. Quantifying segmental fat distribution may aid in better assessment of excess weight and, potentially, the associated health risks.

Childhood obesity is a widespread individual and public health challenge that is exacerbated in populations with disabilities such as spina bifida.[1,2] Recent reports have shown that roughly 17% of children and adolescents in the US are overweight or obese,[3] while as many as 50% to 83% of children and adolescents with spina bifida are overweight or obese.[1,4] Children with myelomeningocele, the most common and severe form of spina bifida, face a multitude of complex and interrelated issues that make obesity difficult to treat.[1, 2] As overweight and obesity may lead to significant health problems, having an accurate assessment of body composition may help direct treatment and decision making.[5–10]

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When evaluating obesity, assessment of fat distribution, not just overall fatness, is important because not all fat has the same effect on health.[11] Although sequelae such as metabolic syndrome, diabetes, hypertension, sleep apnea, and joint pain are generally associated with overweight and obesity,[5,6] the distribution pattern of adipose tissue may provide additional insight into the negative health risks associated with excess adiposity. For example, insulin resistance is higher in children with preferential adipose accumulation in the abdomen compared to the extremities (android vs gynoid obesity).[12] Also, visceral fat is more strongly associated with negative health outcomes than subcutaneous fat.[11–14] Visceral fat has been clearly linked to type 2 diabetes, insulin resistance, kidney and liver inflammation, and cardiovascular disease, while subcutaneous fat appears only weakly related to these outcomes or may even be metabolically protective.[11]

Body fat can be assessed using several methodologies, each of which has advantages and disadvantages. Body mass index (BMI) is simple, fast, and inexpensive; however, it assesses only overall body proportions (weight for height), not fatness or body composition.[11,15] Skinfold thickness is also cost effective and quick but only assesses subcutaneous fat.[16] Body fat measurement by water or air displacement may be difficult to administer in pediatric populations, particularly in populations with physical disabilities. Computed tomography is a highly accurate method for assessing distribution of fat but requires ionizing radiation.[11] Magnetic resonance imaging is also accurate and precise without ionizing radiation, but is expensive and not readily accessible.[11] Dual X-ray absorptiometry (DXA), while still an indirect measure of fat distribution,[11] is simple to perform, suitable for all ages and physical abilities, and allows measurement of different tissues (bone, lean soft tissue, and fat) throughout the body.[17]

Obesity is common and difficult to treat in children and adolescents with myelomeningocele. Moreover, being obese as a child increases the chance of obesity as an adult,[9] and with the increased life expectancy in the myelomeningocele population, the likelihood of encountering diseases that manifest later in life is also increased. Additionally, these diseases may appear earlier in life in this population. Because obesity has been linked to immediate and long-term health issues[5,6,11–14] it is important to understand the risk of developing obesity-related diseases in children and adolescents with myelomeningocele. Having an accurate description of fat distribution may help to elucidate the extent to which children and adolescents with myelomeningocele have an elevated risk for negative health outcomes because of obesity. Therefore, the purpose of this study was to evaluate quantitatively fat distribution in children and adolescents with myelomeningocele using DXA. It was hypothesized that children with myelomeningocele would have higher amounts of body fat and that the amount and distribution would vary depending on lesion level.

METHOD

This cross-sectional study included children with myelomeningocele and healthy comparison children between the ages of 6 and 13 years. The participants were part of a larger study focusing on ambulatory children with myelomeningocele, although a few non-ambulatory children with myelomeningocele were included for comparison. Patient group exclusion criteria included chronic conditions other than myelomeningocele or

hydrocephalus, metal implants, or current glucocorticoid or seizure medication use. All patients meeting the inclusion and exclusion criteria were invited to participate in the study. Most patients were actively recruited from local pediatric spina bifida clinics by a study recruiter; others were recruited by word of mouth or flyers posted at local California Children's Services medical therapy units. The local clinics and medical therapy units provide services to all children (0– 21 years) with spina bifida, regardless of disease severity, ambulatory ability, or socioeconomic status. The comparison group was a convenience sample of healthy children and adolescents free of chronic diseases, medications affecting growth, development, or bones, and non-removable metal in the body. Some of the comparison group participants were siblings of the patients, others were recruited by word of mouth. All participants and parents provided written informed assent and consent, and all study procedures were approved by the Committee on Clinical Investigations at the Children's Hospital Los Angeles.

Participants with myelomeningocele were classified based on functional neurosegmental levels according to International Myelodysplasia Study Group criteria.[18] Basic anthropometric measures were obtained and a brief interview was conducted regarding sedentary activities. If the participant was able to stand unassisted, height and weight were measured standing barefoot. If the participant needed assistance to stand, then height was measured barefoot supine and weight was measured while sitting in a wheelchair (the weight of wheelchair subtracted). All participants were asked to estimate hours per week they spent watching TV and either playing video games or using the computer.

Participants underwent whole body DXA imaging using a standard clinical densitometer (Delphi W, Hologic Inc., Bedford, MA, USA). A single certified radiology technologist performed the scans and segmented the images into the head, trunk, left and right arm, and left and right leg. Segments were grouped for analysis as whole body (less head), trunk, arms, and legs. Body tissue was categorized as bone, lean soft tissue, or fat. The percentage of fat per segment was determined by dividing segment fat mass by total mass for each segment.

First, clinical characteristics and percentage of body fat (%BF) were compared between the myelomeningocele and comparison participants. Ethnicity was dichotomized into Hispanic versus non-Hispanic because of the predominance of Hispanic patients in our study population. For categorical variables, the X^2 was used; for continuous parameters, the W statistic for normality was used to determine the significance of deviation from normality. If a parameter was significantly different from normality ($p \leq 0.05$), the Man-Whitney Rank-Sum test was used to ascertain the difference between the means. If a parameter was not significantly different from normality, the two-sample Student's *t*-test was used.

For comparison of the outcome measures (%BF) between the myelomeningocele and comparison groups, unadjusted and adjusted differences of the means and their 95% confidence intervals (CI) were used. Analysis of covariance was used to derive the adjusted differences between the two groups. Covariates were selected based on clinical importance. Because it has been well documented that children with myelomeningocele have short stature and tend to weigh less than other children the same age,[19] height, weight, and BMI

were included as covariates. In addition, because physical activity is directly related to body composition and children with myelomeningocele may be less physically active than children without myelomeningocele because of disability, TV time was included as a covariate. Lastly there are known differences in body composition due to ethnicity,[13] so ethnicity was also included as a covariate. Therefore, the final multivariate model included height, weight, BMI, TV time, and ethnicity as covariates. While it is known that BMI and %BF are highly related, BMI was included in the model to account for expected differences in BMI between children with myelomeningocele and children without myelomeningocele. The analysis was also performed using the same model with BMI excluded. All differences were initially analyzed between the comparison and myelomeningocele groups, but because of known differences in body composition between sexes,[1,20] the analysis was also done for male and female subgroups.

The differences in clinical characteristics and %BF among the different functional neurosegmental levels (sacral, low lumbar, mid lumbar and above) and comparison individuals were examined using analysis of variance; Dunnett's test was used to identify the neurosegmental groups that were significantly different from the comparison group. Multivariate analysis was not done for the neurosegmental groups because of the limited sample size. All statistical analyses were performed using BMDP Statistical Software (BMDP Statistical Software, Inc. Release 8.1, 2000, Statistical Solutions, Saugus, MA, USA).

RESULTS

Participants in the study included 82 children with myelomeningocele (45 males, 37 females; mean age of 9y 8mo, SD 2y 7mo and 119 comparison individuals (65 males, 54 females; mean age 10y 4mo, SD 2y 4mo; Table I). The distribution of International Myelodysplasia Study Group levels for the participants with myelomeningocele was 22 sacral, 13 low lumbar, and 47 mid lumbar and above. All participants were ambulatory at the time of the test, except for four participants in the mid lumbar and above group who were non-functional ambulators or non-ambulators.

Myelomeningocele group versus the comparison group

The comparison and myelomeningocele groups did not differ significantly in terms of sex, age, Tanner stage of sexual maturity, or time spent using a computer/video games. However, the myelomeningocele group was shorter, weighed less, and watched significantly more TV than the comparison children (Table Ia). BMI (kg/m^2) did not differ significantly between groups. The myelomeningocele group had a higher percentage of Hispanic patients than the comparison group (Table Ia).

Before adjustment for covariates, the myelomeningocele group had a significantly higher total %BF compared to the controls (35.2% vs 29.8%; difference 5.4%; 95% CI 3.0%–7.9%; $p<0.001$), with differences occurring in all subregions though the difference was not significant in the arms (Table II). After adjusting for covariates, the difference between groups for total %BF remained with an adjusted total %BF of 33.6% for the myelomeningocele group and 30.9% for the comparison participants (difference 2.7%; 95%

CI 0.4%– 5.0%; p=0.02; Table II). There was no difference between groups for the trunk (p=0.30) or arms (p=0.61), but the myelomeningocele group (41.9%) continued to have a significantly higher percentage of leg fat compared to the comparison group (34.7%; difference 7.2%; 95% CI 4.7%– 9.7%; p<0.001).

Similar results were observed for the male and female subgroups. Before adjustment, females with myelomeningocele had a higher %BF in all regions, while males with myelomeningocele only had higher %BF in the legs and overall (Table II). After adjustment, both males and females with myelomeningocele had higher %BF than comparison participants in the legs and overall, but not in the trunk and arms. Similar results were also obtained using the model without BMI.

Neurosegmental levels

Among the different functional neurosegmental levels, the mid lumbar and above group was shorter and had a higher BMI than the comparison group; they also watched significantly more TV and had a higher percentage of Hispanic participants (Table Ib). The low lumbar group was slightly younger and shorter than the comparison group. There were no significant differences in clinical characteristics between the sacral and comparison groups.

The mid lumbar and above group had a significantly higher %BF overall and in each subregion compared to comparison participants ($p \leq 0.04$; Table III). The low lumbar and sacral groups had a significantly higher percentage of leg fat than the comparison group ($p \leq 0.05$) with no difference in the other regions.

DISCUSSION

Obesity and inactivity are major challenges that are heightened in children with disabilities such as myelomeningocele.[1] These children have decreased muscle function and ambulatory ability, which may contribute to obesity and the development of obesity-related conditions such as diabetes and cardiovascular disease. Past studies have shown that visceral fat, which accumulates centrally, is more strongly associated with negative health outcomes than subcutaneous fat, which predominates peripherally.[11,13] This study showed that children and adolescents with myelomeningocele have more total body fat than comparison children, primarily because of excess adiposity in the lower extremities. Since the excess fat accumulates peripherally, rather than centrally, it could have less of a negative health impact. While trunk fat is elevated in females with myelomeningocele, this difference disappears in the adjusted analysis. This suggests that the increased trunk fat is primarily associated with greater obesity, rather than being characteristic of myelomeningocele.

These results are consistent with a previous study using skinfolds, which found that children with spina bifida have increased fat in the arms and trunk, but even greater increases in the legs.[4] This is not surprising because myelomeningocele predominantly affects the lower extremity muscles, and areas with chronic muscle paresis have increased subcutaneous and intramuscular fat.[20,21] The current study did not find increased fat in the trunk and arms after adjustment for covariates, in contrast to Hayes-Allen and Tring's study.[4] This

difference may be a result of differences in measurement methodologies, distribution of neurosegmental levels, and/or adjustment for covariates in the current analysis.

While past studies have shown that overweight and obesity are severe problems in children and adolescents with myelomeningocele,[4,19,22–26] the majority of these studies assessed only total body or subcutaneous fat, not fat distribution. The current study found an average of 35% total body fat in children with myelomeningocele, which is consistent with past research where values ranged from 21%[4] to 55%.[26] This large range of body fat values may be, at least in part, caused by differences in patient populations and measurement methodologies.

Some studies, including the current study, show a positive relationship between %BF and lesion level,[23, 25] while others show no relationship.[19,27] Shepherd et al. found higher than normal %BF for mid and high level lesions but not low level lesions.[23] Mita et al. also found a higher percentage of body fat in those with higher level lesions.[25] On the other hand, Roberts et al. found that all participants with myelomeningocele, regardless of neural group, had higher percentages of total body fat than individuals with typical development,[19] and Ausili et al. found no difference in %BF between ambulatory and non-ambulatory children with myelomeningocele.[27] The current study found that children with high level lesions (mid lumbar and above) had a greater percentage of leg and arm fat than those with lower level lesions and comparison participants, and that only these children had greater than normal fat in the trunk. Because the level of lesion largely determines physical ability in children with myelomeningocele, it is not surprising that children with higher level lesions had more fat because of difficulty maintaining an energy balance, greater muscle paresis and atrophy, and increased adipocytes in the atrophied tissue.[21] However, since adjustment for covariates was not done in the neurosegmental subgroups, it remains unknown whether these differences, particularly the difference in trunk fat, are simply caused by greater obesity in the mid lumbar and above group. If this is the case, as in the main comparison of the combined neurosegmental levels to the comparison group, it would suggest that increased trunk fat is more closely associated with general obesity rather than myelomeningocele.

A limitation of this study is that DXA cannot differentiate among different fat depots within a specified anatomic region. In this study, trunk fat was used as a surrogate for visceral fat because visceral fat could not be directly measured. Further research is needed using three-dimensional imaging techniques such as computed tomography or magnetic resonance imaging to differentiate between subcutaneous fat, visceral fat, and intramuscular or intermuscular fat. Ambulatory ability is another factor that warrants further investigation since walking loads bones and stimulates bone growth, which inherently influences body composition. Although ambulatory ability was not directly examined in this study, it should be related to the International Myelodysplasia Study Group classification, which is based on manual muscle testing. Additionally, although the total sample size of 82 children and adolescents with myelomeningocele is fairly large, the neurosegmental subgroups were not large enough for multivariate analysis. Therefore, the findings for the neurosegmental subgroups should be considered preliminary. A final limitation is that the study sample consisted primarily of Hispanic participants, which is representative of the clinic where the

patients were recruited. While this may limit the generalizability of the results among other ethnic groups, it provides important clinical information since spina bifida has a higher prevalence rate among the Hispanic population compared to other ethnic groups.[28, 29]

In conclusion, children with myelomeningocele have more body fat than children with typical development because of excess fat accumulation in the lower extremities. Children with higher level lesions (mid lumbar and above) also have increased trunk fat, which may be suggestive of a greater risk of developing obesity-related diseases.[11–13] Identifying individuals with increased central adiposity may allow for closer monitoring of these individuals and earlier intervention to prevent or treat obesity-related conditions. Therefore, to better manage the health risks of excess weight in children with myelomeningocele, it may be clinically useful to measure fat distribution and separate fat in the extremities from fat in the trunk.

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ABBREVIATIONS

DXA	Dual-energy X-ray absorptiometry
%BF	Percentage of body fat

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What this paper adds

- Children with myelomeningocele have more body fat than children with typical development
- Excess fat in children with myelomeningocele accumulates primarily in the lower extremities.
- Children with myelomeningocele with higher level lesions have increased trunk fat.

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Table I

a: Comparison of demographic and clinical characteristics between the myelomeningocele and comparison groups

Characteristic	Comparison (*n*=119)	MM (*n*=82)	*p*[a]
Age (y:mo), mean (SD)	10y 4mo (2y 4mo)	9y 8mo (2y 7mo)	0.07
Sex, Male/Female, *n*	65/54	45/37	>0.999
Ethnicity, *n* (% Hispanic)	89 (75)	75 (92)	0.003
Tanner stage, *n* (%)			
1	53 (44)	47 (57)	
2	14 (12)	7 (8)	
3	19 (16)	8 (10)	
4	17 (14)	7 (8)	
5	16 (13)	13 (16)	0.29
TV (hours/week), mean (SD)	8.4 (7.1)	11.8 (7.2)	<0.001
Computer/video games (hours/week), mean (SD)	6.1 (7.3)	5.2 (6.1)	0.30
Height (cm), mean (SD)	142.5 (15.2)	130.0 (17.4)	<0.001
Weight (kg), mean (SD)	42.0 (16.1)	37.6 (18.7)	0.01
BMI (kg/m^2), mean (SD)	20.0 (4.7)	21.0 (6.1)	0.32

b: Comparison of demographic and clinical characteristics among neurosegmental and comparison groups

Characteristic	Comparison (*n*=119)	Sacral (*n*=22)	Low lumbar (*n*=13)	Mid lumbar and above (*n*=47)	*p*
Age (years), mean (SD)	10y 4mo (2y 4mo)	9y 11mo (2y 10mo)	8y 4mo (2y 0mo)[a]	10y 0mo (2y 7mo)	0.04
Sex, Male/Female, *n*	65/54	10 (46%)	6 (46%)	29 (62%)	0.56
Ethnicity, *n* (% Hispanic)	89 (75)	18 (82)	12 (92)	45 (96)[b]	0.01
Tanner stage, *n* (%)					
1	53 (44)	11 (50)	9 (69)	27 (57)	
2	14 (12)	1 (5)	1 (8)	5 (11)	
3	19 (16)	3 (13)	1 (8)	4 (9)	
4	17 (14)	1 (5)	2 (15)	4 (9)	0.29
5	16 (13)	6 (27)	0 (0)	7 (14)	0.01

b: Comparison of demographic and clinical characteristics among neurosegmental and comparison groups

Characteristic	Comparison (*n*=119)	Sacral (*n*=22)	Low lumbar (*n*=13)	Mid lumbar and above (*n*=47)	*p*
TV (hours/week), mean (SD)	8.4 (7.1)	11.3 (8.1)	10.3 (4.7)	12.4 (7.3)[b]	0.01
Computer/video games (hours/week), mean (SD)	6.1 (7.3)	5.6 (6.5)	5.8 (6.7)	4.8 (5.8)	0.76
Height (cm), mean (SD)	142.5 (15.2)	136.1 (19.6)	123.8 (15.4)[b]	128.8 (16.3)[b]	<0.001
Weight (kg), mean (SD)	42.0 (16.1)	38.4 (20.8)	2.39 (10.8)	39.5 (19.2)	0.08
BMI (kg/m^2), mean (SD)	20.0 (4.7)	19.4 (5.2)	18.4 (3.1)	22.5 (6.7)*	0.01

[a]Chi-square test was used for proportions. Mann-Whitney Rank-Sum was used for means as the W statistic for test of normality was rejected at the 0.05 level of significance for all continuous factors. MM, myelomeningocele; BMI, body mass index.

For categorical variables the Chi-square test was used; for continuous variables analysis of variance was used to compare the four groups. Dunnett's test for multiple comparisons was used to compare each neurosegmental group with the comparison group.

[a]Denotes significant difference from comparison group at 0.05 level.

[b]Denotes significant difference from comparison group at 0.01 level. BMI, body mass index.

Table II

Comparison of percentage of body fat between myelomeningocele and comparison groups – all participants

	Unadjusted				Adjusted for ethnicity, TV time, height, weight, BMI			
Region	**Comparison (*n*=119) Mean (SD)**	**MM (*n*=82) Mean (SD)**	**Diff of Mean (MM – Comparison) (95% CI)**	***p***	**Comparison (*n*=119) Mean (SD)**	**MM (*n*=82) Mean (SD)**	**Diff of Mean (MM – Comparison) (95% CI)**	***p***
Trunk	25.6 (9.0)	29.2 (9.5)	3.6 (1.0, 6.2)	0.007	26.6 (8.0)	27.6 (9.0)	0.9 (−1.4, 3.3)	0.30
Leg	33.5 (7.5)	43.6 (9.1)	10.1 (7.8, 12.4)	<0.001	34.7 (8.6)	41.9 (9.6)	7.2 (4.7, 9.7)	<0.001
Arm	33.5 (11.1)	36.6 (9.8)	3.0 (0.03, 6.0)	0.05	35.0 (10.5)	34.4 (11.6)	−0.6 (−3.7, 2.5)	0.61
Total	29.8 (8.4)	35.2 (9.0)	5.4 (3.0, 7.9)	<0.001	30.9 (7.8)	33.6 (8.6)	2.7 (0.4, 5.0)	0.02
	Male subgroup							
	Comparison (*n*=65) Mean (SD)	**MM (*n*=45) Mean (SD)**	**Diff of Mean (MM – Comparison) (95% CI)**	***p***	**Comparison (*n*=65) Mean (SD)**	**MM (*n*=45) Mean (SD)**	**Diff of Mean (MM – C) (95% CI)**	***p***
Trunk	24.7 (9.7)	27.4 (9.7)	2.7 (−1.0, 6.4)	0.16	25.5 (9.3)	26.2 (10.5)	0.6 (−3.1, 4.4)	0.63
Leg	32.1 (8.6)	42.2 (9.7)	10.1 (6.6, 13.6)	<0.001	33.2 (10.2)	40.7 (11.5)	7.6 (3.4, 11.7)	<0.001
Arm	32.8 (12.3)	34.7 (10.6)	1.9 (−2.6, 6.4)	0.40	34.2 (12.8)	32.6 (14.5)	−1.6 (−6.8, 3.6)	0.37
Total	28.7 (9.5)	33.5 (9.5)	4.8 (1.2, 8.5)	0.02	29.6 (9.4)	32.2 (10.6)	2.6 (−1.2, 6.4)	0.051
	Female subgroup							
	Comparison (*n*=54) Mean (SD)	**MM (*n*=37) Mean (SD)**	**Difference of mean (MM – Comparison) (95% CI)**	***p***	**Comparison (*n*=54) Mean (SD)**	**MM (*n*=37) Mean (SD)**	**Difference of mean (MM – Comparison) (95% CI)**	***p***
Trunk	26.6 (8.1)	31.3 (9.0)	4.7 (1.1, 8.3)	0.01	28.3 (6.6)	28.9 (7.2)	0.7 (−2.2, 3.6)	0.58
Leg	35.3 (5.4)	45.3 (8.1)	10.0 (7.2, 12.8)	<0.001	36.7 (6.8)	43.2 (7.4)	6.5 (3.5, 9.5)	<0.001
Arm	34.5 (9.6)	38.9 (8.4)	4.4 (0.53, 8.3)	0.03	36.3 (8.3)	36.3 (9.2)	0.04 (−3.6, 3.7)	0.98
Total	31.1 (6.9)	37.3 (8.0)	6.2 (3.1, 9.3)	<0.001	32.6 (5.8)	35.0 (6.4)	2.3 (−0.2, 4.9)	0.03

A 2-sample Student's t-test was used to compare the means of the two groups. Analysis of covariance was used to compare the means adjusted for covariates. BMI, Body mass index; MM, myelomeningocele.

Table III

Comparison of percentage of body fat among myelomeningocele neurosegmental groups and comparison group

Region	Comparison (*n*=119) Mean (SD)	Sacral (*n*=22) Mean (SD)	Low lumbar (*n*=13) Mean (SD)	Mid lumbar and above (*n*=47) Mean (SD)	*p*
Trunk	25.6 (9.0)	25.8 (9.5)	26.9 (9.1)	31.4 (9.2)[b]	0.003
Leg	33.5 (7.5)	37.9 (7.2)[a]	39.7 (6.4)[a]	47.3 (8.8)[b]	<0.001
Arm	33.5 (11.1)	34.6 (9.9)	34.6 (9.9)	38.1 (9.7) [a]	0.11
Total	29.8 (8.4)	31.5 (8.5)	32.5 (8.0)	37.7 (8.7)[b]	<0.001

Analysis of variance was used to compare the four groups. Dunnett's test for multiple comparisons was used to compare each neurosegmental group with the comparison group.

[a] Denotes significant difference from comparison group at 0.05 level.

[b] Denotes significant difference from comparison group at 0.01 level.