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Original Article

Assessment of Changes in Lumbar Vertebra According to Body Weight

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Abstract:

Background: Increasing overweight and obesity is a serious public health problem worldwide. Due to excess mechanical load on spine due to high BMI wear and tear effect occur on vertebra. Radiograph of lumbar spine is an accurate and reproducible method of knowing the morphological variation of lumbar spine in adults. **Objectives:** The present study was attempted to document and evaluate radiologically the effect of overweight and obesity on morphometric changes of lumbar part of vertebral column. **Methods:** This cross-sectional, analytical study was conducted at Department of Anatomy of Rangpur Medical College, Rangpur between the period of July 2018 and June 2019. 124 X-ray films fulfilling the selection criteria were enrolled into this study and these digital X-ray plates were collected from Crescent diagnostic and imagining center Lalmonirhat. Age range of the persons was 20 to 45 years. Among them 62 X-ray films was obtained from adult male (Group A-normal weight, B-overweight, C-obese) and 62 X-ray films was obtained from adult female (Group A-normal weight, B-overweight, C-obese).Plain X-ray both antero-porterior (A/P) and lateral view of lumbar spine was done for every subject. With the help of digital slide caliper and flexible ribbon tape different measurements was taken carefully. Prior to radiograph height and weight of each subject was measured and body mass index was calculated. On the basis of all measurements, different data was compared between normal weight, overweight and obese subjects of two sex groups and analyzed by using statistical package for social sciences (SPSS version 16.0). The difference between groups was done students “t test” and regarded statistically significant if the p value was ≤0.05. **Results:** In the present study, regarding variables of lumbar vertebra (LV), it was observed in most levels and both sexes values of the average height (AvH) of the lumbar vertebra was found significantly higher in overweight and obese than normal weight group). Again the transverse diameter (TD) of LV though higher but did not vary significantly between groups specially in females. Moreover, the overall length of LV was though significantly higher in males in obese and overweight than normal weight but in females it vary significantly between normal weight and obese and overweight and obese mostly. Again, male values were significantly higher than females in almost all cases. **Conclusion:** Clearly, weight-bearing and mechanical factors appear to play important roles in morphological and functional adaptation of the vertebral column by increasing size of the vertebra. So, overweight and obesity are definitely associated with a higher risk of problems of spine. This study would help to know the data of Bangladeshi people about lumbar spine as well as would provide information for the clinicians.

Key words: Body weight, Radiographic measurements, Average height (AvG), Transverse diameter (TD), Overall length of Lumbar vertebra

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Introduction:

Human lumbar vertebrae with the intervening intervertebral disc support the weight of the upper part of the body[1]. The body height had a linear effect on spinal load but the spinal effect was stronger for variation of body weight than the body height. Spinal loads generally increase from cranial to caudal[2].

Obesity is called “tsunami of the 21st century”. The term obesity defined as an eccentric load, represented by the mass of the belly leads to the development of many metabolic disorders and diseases and is cause of increased morbidity and mortality. On the other hand, diseases of the musculoskeletal system are now the main cause of disability and the second cause of doctors visits[3]. Obesity negatively affects orthopedic management of nearly all musculoskeletal disease processes[4]. Comparing the first to latest survey in Bangladesh, the prevalence of overweight - obesity increased from 2.7% to 8.9%[5].

BMI and height are linked to the pathogenesis of low back pain, but evidence based confirmation is lacking. Increase mechanical demands resulting from obesity have also been suspected of causing low back pain (LBP) through excessive load bearing[7,8]. Again it has been reported that a (6-10) kg weight loss in morbidly obese subjects is associated with a relief of pain in the lower back[9]. While back pain is prevalent health issue worldwide, it has significant social and economic burdens on individuals and society.

Again wide individual variations within common patterns of LV anatomy may appear. These force the surgeon to understand the individual anatomy of the patient, in order to achieve clinical success, and to appreciate the patterns of lumbar vertebrae anatomy during surgical procedure. As stated earlier, morphometric studies regarding changes in vertebra with age was done by previous authors like Amnoo-Kuofi[10], Atta-Ala et al[11] and Ahamed[12] by radiograph but only a few authors found to be aware about the effect of higher BMI (example as obesity) on the lumbar vertebra. So, the present study was attempted to investigate the various dimensions of the lumbar vertebra correlated with higher BMI (overweight and obese) in both sexes of Bangladeshi people to establish a referable database for medical science. The aim of the present study was to evaluate radiologically the effect of overweight and obesity on average height, transverse diameter and overall length of lumbar part of vertebral column and to compare the variables between normal weight, overweight and obese subjects in both sexes.

Methods:

This study was a cross sectional, analytical type study.This study was performed in the Department of Anatomy, Rangpur Medical College, Rangpur. This study was conducted from July 2018 to June 2019.This study was performed on 124 plain digital X-ray films of adult lumbar spine (both antero-posterior and left lateral view) in both sexes of different body weight groups. The height and weight of subjects taken and BMI was calculated and were divided into three body weight groups according to body mass index (BMI)[13].According to WHO[4] Normal weight is defined as BMI (20–24.9) kg/m^2. Overweight is defined as BMI (25–29.9) kg/m^2. Obesity is defined as BMI (30–39.9) kg/m^2. The subjects were grouped in to A (Normal weight), B (Overweight) and C (Obese) group according to BMI in both sexes included 22, 20 and 20 subjects respectively.Subjects were chosen by convenient purposive sampling as per inclusion and exclusion criteria. The patient who came for another cause in the X ray department was requested for a view of lumbar spine and A-P and lateral view of plain X-ray radiograph was taken. After full explanation informed written consent was obtained from the subject informing details of the purpose of the study. The radiographs were collected from the Radiology Department of a well-known diagnostic center of Rangpur (Crescent diagnostic and imaging center, Lalmonirhat). Subjects with any deformity of lumbar region, congenital anomaly, H/O surgery of lumbar region, any systemic diseases and pregnant females were excluded from the study.The study was approved by the Ethical Review Committee of Rangpur Medical College, Rangpur. Average height (calculated as the mean of anterior height, posterior height, central height), transverse diameter of the body of lumbar vertebra and overall length (Antero posterior) of each lumbar vertebra was also measured on X-ray films. All the measurements were done with the help of standardize plastic measuring scale and digital slide calipers directly on the X-ray films after placing the radiograph vertically on a well illuminated view box and recorded in millimeters. Some landmark points were used for this purpose (Figure 1).

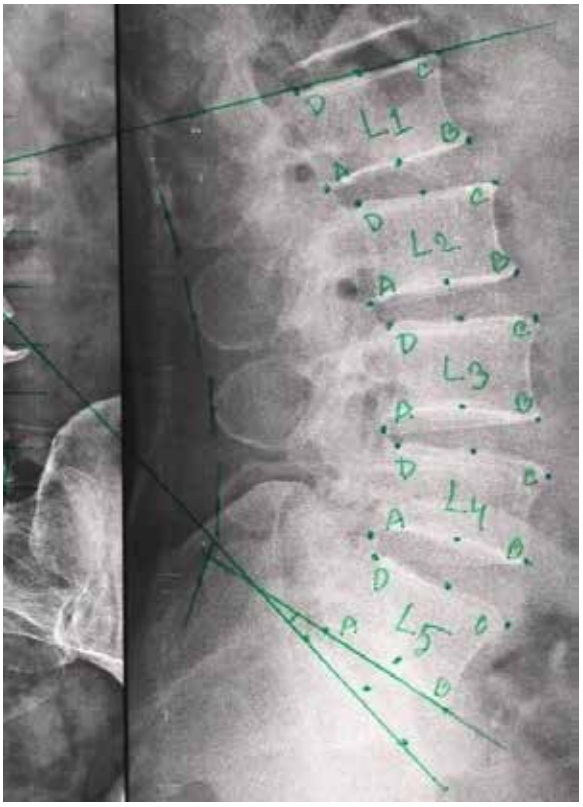


Figure 1: Photograph showing the measurement points of lumbar vertebra

1) C = Most superior – anterior point of vertebral body
2) B = Most inferior – anterior point of vertebral body
3) D = Most superior – posterior point of vertebral body
4) A = Most inferior – posterior point of vertebral body
5) Distance between C to B: anterior height of the body of vertebra
6) Distance between D to A: posterior height of the body of vertebra
7) Central height of the body of vertebra was measured by distance between midpoint of (D to C) and (A to B)[10,11] as shown in Figure 1.

   Transverse diameter of body of lumbar vertebra was measured on antero-posterior view. The digital slide caliper was moved up and down and the narrowest diameter was recorded in millimeter at the narrowest part of the vertebral body shown in Figure 2.



Figure 2: Photograph showing transverse diameter of lumbar vertebra male in anterior posterior view

Overall length of lumbar vertebra was measured as distance from B to maximum outer point of spinous process of that vertebra on lateral view recorded in millimeter by digital slide calipers shown in Figure 3.

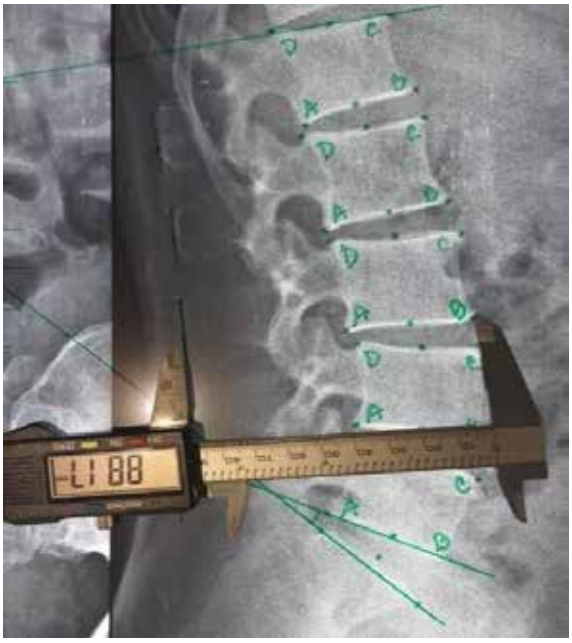


Figure 3: Photograph showing overall (antero-posterior) length of each lumbar vertebra of male inlateral view

Statistical processing of data

The data collected from the radiological measurements were processed according to their distributions, central tendencies, and dispersions. Then results were prepared from these data in terms of ranges, frequency distributions, mean values, standard deviations (SD), percentage value etc. as applicable. Mathematical relationships between measurements of two groups were calculated by statistical analyses such as unpaired Students 't' test. In all statistical analyses the level of significance was set as $p \leq 0.05$ at 95% confidence intervals. All the statistical analyses were done by using the SPSS software package for windows version 16.00.

Results:

Distribution of average height (AvH) of lumbar vertebra in both sexes

Table I shows the average height (AvH) of lumbar vertebra in both sexes in three weight groups. It was observed from that in males, significantly higher mean value of AvH of all lumbar vertebra was found in overweight and obese subjects than normal weight but in female, it was not so at L4 and L5 level between normal weight and overweight and at L5 level between normal weight and obese. However AvH was higher in obese than overweight in both sexes at all levels but the difference was statistically significant only at L4 in females.

Table I: Comparison of average height of lumbar vertebra in between normal weight (n=22), overweight (n=20) and obese (n=20) in both sexes

Average height of lumbar vertebra (mm)	Gender	Normal weight (A)	Overweight (B)	Obese (C)	p value for significant difference between groups (p≤0.05)
L1	Male	30.17 ± 1.66 27.2-33	31.99 ± 1.51 29.57-30.03	32.74 ± 1.64 29.87-35.93	A vs B = S A vs C = S B vs C = NS
	Female	27.80 ± 1.91 24.5-30.33	29.33 ± 1.58 26-32.67	30.15 ±2.19 26.47-34.57	A vs B = S A vs C = S B vs C = NS
L2	Male	30.41 ± 1.77 27.87- 35	32.11 ± 1.31 29.6-35.14	32.79 ± 1.56 30.67-35.8	A vs B = S A vs C = S B vs C = NS
	Female	28.21 ± 1.70 24.8-31	29.93 ± 1.71 27-34	30.97 ± 1.94 26.47-34.67	A vs B = S A vs C = S B vs C = NS
L3	Male	30.50 ± 1.54 27.73-34	32.69 ± 1.63 29.67-35.3	32.85 ± 1.42 30.2-35.13	A vs B = S A vs C = S B vs C = NS
	Female	28.34 ± 1.77 24.43-30.67	30.00 ± 1.76 27-33.33	31.02 ± 1.79 28.38-34	A vs B = S A vs C = S B vs C = NS
L4	Male	29.72 ± 1.86 27.03-33.27	31.55 ± 1.80 28.67-34.63	31.90 ± 1.42 29.77-34.53	A vs B = S A vs C = S B vs C = NS
	Female	27.63 ± 1.85 23.03-30.67	28.49 ± 1.58 25-31.33	30.06 ± 2.03 26.73-34	A vs B = NS A vs C = S B vs C = S
L5	Male	28.84 ± 1.89 24.73-31.77	30.90 ± 2.18 26-35.57	30.74 ± 1.60 25.9-33.67	A vs B = S A vs C = S B vs C = NS
	Female	27.59 ± 2.79 21.63-33.37	27.63 ± 1.75 23.67-31.33	28.87 ± 2.12 23.67-33	A vs B = NS A vs C = NS B vs C = NS

Results are shown as range and mean ±SDs

Comparison between normal weight, overweight and obese male and female were found to be significant at $p<0.05$ in unpaired student's "t" test.

S= Significant

NS= Non-significant

Distribution of Transverse diameter (TD) of lumbar vertebra in both sexes

Table II shows the transverse diameter (TD) of lumbar vertebra in both sexes in three weight groups.It was observed that in male, significantly higher mean value of TD of all lumbar vertebras was found in overweight and obese subjects than normal weight except at L1 between normal weight and overweight. However in females, though higher mean values were found in overweight and obese than normal weight but reached significant level between normal weights and obese at L5 only. Although TD was higher in obese than overweight but the difference did not reach statistically significant level in all level of both sexes.

Table II: Comparison of transverse diameter of lumbar vertebra in between normal weight (n=22), overweight (n=20) and obese (n=20) in both sexes

Transverse diameter of bodies of lumbar vertebra (mm)	Gender	Normal weight (A)	Overweight (B)	Obese (C)	p value for significant difference between groups (p≤0.05)
L1	Male	41.32 ± 3.03 36-48.2	42.39 ± 2.79 37-47.5	43.68 ± 2.97 39.4-51	A vs B = NS A vs C = S B vs C = NS
	Female	37.98 ± 2.97 31.85-45	38.45 ± 2.04 35-43	38.75 ±2.32 36-44	A vs B = NS A vs C = NS B vs C = NS
L2	Male	41.97 ± 3.14 37-50	43.95 ± 2.83 37-49	45.21 ± 3.41 40-52	A vs B = S A vs C = S B vs C = NS
	Female	39.46 ± 3.15 34.27-44.7	40.40 ± 2.62 35-46	40.80 ± 2.64 37-46	A vs B = NS A vs C = NS B vs C = NS
L3	Male	44.47 ± 3.57 39.4-53.3	46.52 ± 2.84 38-50.6	48.00 ± 3.63 40.5-54.7	A vs B = S A vs C = S B vs C = NS
	Female	41.88 ± 3.52 36.29-46.7	42.95 ± 2.48 39-49	43.57 ± 2.15 40-47	A vs B = NS A vs C = NS B vs C = NS
L4	Male	47.40 ± 3.22 42.3-54.7	49.84 ± 3.79 42-57.6	50.86 ± 3.58 43.8-59	A vs B = S A vs C = S B vs C = NS
	Female	44.93 ± 3.51 37.18-51	46.10 ± 2.43 41-52	46.31 ± 1.85 44-50	A vs B = NS A vs C = NS B vs C = NS
L5	Male	53.56 ± 3.71 47.7-60.4	56.10 ± 3.79 45-63.4	57.18 ± 3.68 51-62.3	A vs B = S A vs C = S B vs C = NS
	Female	49.65 ± 4.61 42.58-57.3	51.80 ± 3.07 46-59	52.59 ± 2.35 50-57	A vs B = NS A vs C = S B vs C = NS

Results are shown as range and mean ± SDs

Comparison between normal weight and overweight and obese in male and female were found to be significant at $p<0.05$ in unpaired student's "t" test.

S= Significant

NS= Non-significant

Distribution of overall (antero-posterior) length (OL) of lumbar vertebra in both sexes

Table III shows the overall (antero-posterior) length (OL) of lumbar vertebra in both sexes in three weight groups.

It was observed that in male, significantly higher mean value of OL of all lumbar vertebra was found in overweight and obese subjects than normal weight. In females significantly higher value was found in obese than normal weight at all levels. Although in males OL was higher in obese than overweight but the difference did not reached statistically significant level but in females the difference was significantly higher in all vertebra except at L5 level.

Table III: Comparison of overall length of lumbar vertebra in between normal weight (n=22), overweight (n=20) and obese (n=20) in both sexes

Overall diameter (mm)	Gender	Normal weight (A)	Overweight (B)	Obese (C)	p value for significant difference between groups (p≤0.05)
L1	Male	83.35 ± 3.54 77.3-90.4	88.31 ± 3.65 81-99	90.38 ± 4.29 83-101	A vs B = S A vs C = S B vs C = NS
	Female	77.37 ±4.40 70.7-85	79.94 ± 4.89 74-93	83.19 ±5.02 76-94	A vs B = NS A vs C = S B vs C = S
L2	Male	86.44 ± 3.67 80.4-95	91.98 ± 3.95 85-103	94.59 ± 4.66 86-102	A vs B = S A vs C = S B vs C = NS
	Female	81.70 ± 4.66 74.3-90	83.89 ± 5.38 76-97	87.42 ± 5.39 78-97	A vs B = NS A vs C = S B vs C = S
L3	Male	87.78 ± 3.75 80.4-94.5	93.65 ± 4.87 87-105	95.83 ± 4.83 89-107.5	A vs B = S A vs C = S B vs C = NS
	Female	83.40 ± 4.31 74.6-92	84.95 ± 5.83 72-97	88.62 ± 5.17 81-99	A vs B = NS A vs C = S B vs C = S
L4	Male	86.87 ± 4.04 79.3-92	92.34 ± 5.72 81-102.4	93.10 ± 5.16 85-105	A vs B = S A vs C = S B vs C = NS
	Female	81.44 ± 4.12 74.6-88	83.00 ± 5.93 70-96	87.11 ± 5.87 77-100	A vs B = NS A vs C = S B vs C = S
L5	Male	80.78 ± 4.41 74-94.5	85.65 ± 6.18 74-94.4	87.56 ± 5.71 79-99	A vs B = S A vs C = S B vs C = NS
	Female	76.32 ± 4.59 66-84	78.30 ± 6.22 66-88	81.79 ± 5.29 70-92	A vs B = NS A vs C = S B vs C = NS

Results are shown as range and mean ± SDs

Comparison between normal weight, overweight and obese male and female were found to be significant at $p<0.05$ in unpaired student's "t" test.

S= Significant

NS= Non-significant

Discussions:

The primary function of vertebra in lumbar region is that they provide resiliency to the vertebral column specially for resistance to compression and act as shock absorber. It is believed that the relationship between obesity and musculoskeletal disease is complex involving biomechanical, dietary, genetic, inflammatory and metabolic factors. Excess body weight has long been claimed to be related to many symptoms and diseases of muscles and bone. A good knowledge of morphological change in vertebra due to obesity is relevant for a successful treatment and surgery. The aim of the present study was to find out radiologically the effect of overweight and obesity on morphometric changes of lumbar vertebra to ensure distribution of compressive forces to the upper and lower surface of vertebral bodies. Most of the previous studies were done to find out the effects of aging on lumbar vertebra. Another aim of the present study was whether the effect of high BMI on lumbar vertebra was similar to aging.

Average height (AvH) of lumbar vertebral body

It was observed that, in the sequence of normal weight, overweight, obese average height of each vertebra showed gradual increase pattern of mean value of AvH both in male and female.

Significantly higher value of AvH was observed in B and C groups than A in both sexes at all levels except L5 of female. Again though higher value was found in C than B but did not reach statistically significant level.

In male, highest mean value was found 32.85 mm at L3 level in obese and lowest value was also found 28.84 mm at L5 level in normal weight. In female highest mean value was found 31.02 mm at L3 level in obese and lowest value was found 27.59 mm at L5 level in normal weight.

Craniocaudally, there was gradual increase in AvH from L1 to L3 then decrease at L4 and L5 in both sexes of all groups.

By reviewing AvH of lumbar vertebra of different groups of people it was observed that highest value of AvH of lumbar vertebra was found among people of Rajshashi by Ahmed[12], 33.62 mm at L3 level in male in 3rd decades, 31.72 mm in female at L3 level in 4th decades and lowest value 29.92 mm at L5 level in male in 4th decades and 29.02 mm in female at L1 level in 3rd decades. So, morphometric studies published by the author showed a gradual cephalo-caudal increase then decrease in average height of lumbar vertebra related with age and gender. In sequence of decades, the average height of lumbar vertebra, in most instances showed an alternate increase and decrease pattern.Although this study was related with age change and gender but present study was related only with BMI but there was some similarity of this result with present study.

Transverse diameter (TD) of lumbar vertebra

It was observed that, in the sequence of normal weight, overweight, obese TD of lumbar vertebra showed gradual increase pattern of mean value both in male and female. The differences reached a statistically significant level mostly in males (A vs C at L1, A vs B and A vs C at L2, L3, L4 and L5) and in females statistically significant difference was found only at L5 between A vs C.

In male, highest mean value was found 57.18 mm at L5 level in obese and lowest value was also found 41.32 mm at L1 level in normal weight. In female highest mean value was found 52.59 mm at L5 level in obese and lowest value was found 37.98 mm at L1 level in normal weight.

It is also important to mention that the mean TD of lumbar vertebra increased craniocaudally from L1 to L5 in normal weight, overweight and obese in both sexes.

It was found that highest value of transverse diameter of lumbar vertebra was found among people of Western Australia by Taylor and Twomey[18] were 52.2 mm in male and 46.6 mm in female at L5 level and lowest value were 42.2 mm in male and 36.1 mm in female at L1 level in adult. On the other hand highest value of transverse diameter of lumbar vertebra was found by Gocmen-Mas et al[17] (on MRI) among people of Turkey male and female where value was found 57.3 mm in L5 and lowest value was 48.8 mm at L1 vertebra level in male and highest value was found 57.2 mm at L5 and lowest value was 47.8 mm at L1 vertebra level in female. Gupta et al[19] studied 210 Indian people where the highest value was 43.3 mm at L5 level and the lowest value was 38.3 mm at L1 level. In

another study in India, Jadhav et al[20] studied among the Western Maharastra male and female where highest value was found 45.44 mm at L5 and lowest value was 36.19 mm at L1 vertebra level in male and highest value was found 31.64 mm at L5 and lowest value was 33.34 mm at L1 vertebra level in female. Atta-Alla et al[11] worked on Lebanese women whom are normal weight where highest value was found 57.1 mm at L5 and lowest value was 38.9 mm at L1 level. So, various studies published by different authors showed a gradual cephalo-caudal increase in transverse diameter of lumbar vertebra related with age and gender. In sequence of decades, the transverse diameter of lumbar vertebra, in most instances in gradual increase pattern.Although these type of study related with age change and gender but present study was related with BMI and there was similarity of their result with present study.

Overall length (antro posterior) of lumbar vertebra

In the present study, overall length of lumbar vertebra was increased gradually from L1 to L3 then decreased at L4 and L5 than L3 in both sexes. Gilad and Nissan[15] found similar result that higher value of overall length of LV from L1 to L3 then decreased at L4 and L5.

When comparison was done between groups, it was observed that values increased in overweight and obese groups than normal weight, more specifically in males. In males, significantly higher value was found in B and C groups than A at all levels but the difference was non-significant between B and C groups. In females, on the other hand, a non-significant higher value was found in B than A and reached significant higher level between A and C and B and C except at L5. This suggested that in male both overweight and obese groups were affected similarly but in females obese group was affected more than overweight and normal weight groups.

In summary, in the present study, regarding AvH, TD and overall length of LV, similar result was observed, such that values were mostly significantly higher in B and C groups than A group in both sexes. Again value in C group was found higher than B group but did not reached significant level.Craniocaudally, in most cases, a linear pattern of increase value was observed upto L3 or L4 level and again decreased at L4 or L5 level in both sexes. However, in works of most authors effects of high BMI on LV was not found. They compare the effect of ageing on LV.

Higher values of AvH, TD and oveall length(in most cases) of LV in B and C groups than A group indicates active compensatory growth of the vertebral height in overweight and obese groups of both sexes to support higher bodyweight.

Zukowsky et al[21] found in females, as BMI increased, osteophyte severity increased in the vertebral bodies suggested an adaptive response to increased loading. Because females generally have vertebral bodies that are narrower than those of males of the same weight, the smaller cross sectional area of their vertebral bodies is stressed more than with a comparable load in males. This fact explains the increase in height of lumbar vertebra in females but not in males.

Numerous observations indicate a positive correlation between BMI and bone mass. It was observed for both sexes, although most visible in post-mesopausal women[22,23]. The authors of one of the papers calculated that a 10-kg increase in body weight was related to an improvement in bone mineral density by 1%[24]. The mechanisms explaining the correlation include intensified aromatization processes in a larger volume of fat tissue, with subsequent increase in the pool of estrogens, the hormones which are a key factor in maintaining bone mass. Also the mechanical effect plays a part, i.e. an increase in pressure forces on bones resulting from an increased body weight. This helps to stop apoptosis, and stimulates proliferation and differentiation of osteoblasts and osteocytes resulting in bone growth[25].

Also in the present study, it was observed that vertebral body height and transverse diameter was increased gradually in overweight and obese than normal weight subjects. Mavrych et al[16] found similar results with increase of age. So it could be suggested that high BMI cause effect on vertebral dimensions similar to ageing process.

Conclusions:

In the present study, regarding variables of LV, it was observed in most levels and both sexes'

values of AvH, TD and overall length of LV was found significantly higher in overweight and obese than normal weight group. It may be concluded that body weight affect height of lumbar vertebra more in in both sexes.

The vertebras undergo continuous growth and remodeling throughout life presumably in response to changing needs of the body. Hormonal and genetic regulatory factors are thought to be contributory.The growth does not seem to follow a linear pattern. Rather it is characterized by alternating periods of overgrowth and remodeling. This could result from the multiplicity of changes triggered by the temporary loss of height (may be due to high BMI).

The problems of obesity in Bangladesh are increasing day by day as like as the whole world. In light of the perspective of Bangladesh overweight and obesity can turn into big social issues. In the present study on the effects of overweight and obese on the lumbar spine was done and discussed subsequently to aware the people about the negative effects of obesity on their life. So, prevention and control of obesity in developing countries deserve urgent attention.

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