

# Body Mass Index role in Lumbar Sacrum Spine Anterio-Posterior and Lateral Radiography by adjusting the radiation exposure factor mAs & kVp to avoid unnecessary radiation dose in patient- An Observational Study

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## Research Article

**Keywords:** Body Mass Index, L.S Spine AP & Lateral, Radiation dose Reduction, Obese, Overweight

**Posted Date:** January 8th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-131245/v1>

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# Abstract

## Background

- To evaluate the role of BMI values before each L. S. spine radiograph and to choose the optimum radiation exposure factors without compromised the radiographic image quality. The data of BMI values of each patient's and radiation exposure values like mAs & kVp were collected. This study was based on the observation analysis of BMI values with radiation exposure parameters like mAs & kVp. Forty patients were added to this study. Out of which, 26 were female and 14 male patients were added.

## Result

- In the result, the exposure factors were used in the first two categories i.e. normal BMI and overweight BMI were found optimum with good anatomical details and good quality radiographs. But in the rest three BMI categories i.e Pre-Obese, Pre-obese 1, and Obese, the radiation exposure factors were not found appropriate in different BMI values/categories.

## Conclusion

- The study concludes that blind selection of radiation exposure factors (mAs & kVp) for each X-Ray procedure, is unprofessional behavior of radiographer. Appropriate radiation exposure chart, the amount of radiation dose can be reduced by 20–30% without compromising the radiographic image quality.

## Introduction

The clinical application of X-Rays was started almost immediately after the discovery by Sir Wilhelm Conrad Roentgen on 8 November 1895. Since 1895, diagnostic X-Ray equipment has placed their presence in each clinician's center. Discovery of X-Rays tremendously changed the medicine world and worked as eye opener for each clinician & surgeon. As technology get going improved day by day, as the quality of X-Ray images getting improved <sup>(1)</sup>. In New Delhi India, the 1<sup>st</sup> X-Ray equipment was installed at Lady Hardinge hospital in 1918 and a radiology department was established in 1923 in the hospital <sup>(2)</sup>. The role of spine radiography has importance in trauma, lower backache, jerk cases (Sudden or sharp movements of spine), Heavy weight lifting, radiating lower limb pain on either one side or both sides, and in case of metastatic diseases <sup>(3)</sup>.

This study is hypothesized that the role of Body Mass Index (BMI) in the Lumbo-Sacral (L.S) Spine AP & LAT radiography may help in improvement of imaging quality and reduce the amount of patient absorbed dose. This will be beneficial for not only the patients but it will also help the radiographer or radiologist to choose optimum radiation exposure parameters. Which can help in to decrease the amount of radiation dose in each patient and can archive quality X-Rays images. Low or high radiation dose to patient is

harmful, So the responsibility of radiographer is to choose the appropriate radiation exposure for each patient. The major responsibility of the radiographer is to avoid the unnecessary or extra radiation exposure to the patient <sup>(4)</sup>. In the diagnostics, poor X-Ray imaging quality may lead to repeat exposure or false/mis-diagnosis of patient's the disease. The radiation dose in a L.S Spine AP & LAT radiograph for adult is approximately 0.06 mSv <sup>(5)</sup> and this radiation dose is differ from patient to patient.

The density of the tissues at L.S Spine region is different in AP position and it is different in Lateral position. Blindly selection of radiation exposure parameters may lead to unprofessional behavior of the radiographer. Good contrast images are required in each X-Ray procedure. Contrast of the x-ray image was defined according to the different density levels of tissues between the lighter shade to darker shades of gray scale <sup>(6)</sup>. Ionizing radiation has sufficient energy to affect the atoms of living cells and also can damage their genetic material (DNA). Radiation interactions with genetic material of living cell may produce direct and indirect biologic effects <sup>(7)</sup>. It involves rupture of cell membrane and breakdown of chromosomes structure and that is known as DNA strands break <sup>(8)</sup>. For radiation protection radiographer must follow the term "ALARA" (As Low As Reasonably Achievable), and TDS (Time Distance Shielding) principals in his routine practice <sup>(9)</sup>.

In the Anatomy of L.S Spine X-Ray Figure 1a AP view showing the 1. Lower chest ribs, 2. Transverse process, 3. Pedicle, 4. Spinous process, 5. Sacrum, 6. Sacroiliac joint and Figure 1.b lateral view showing the 1. Sacrum, 2. Spinous process, 3. Vertebral body, 4. Intervertebral disc space, 5. Intervertebral foramen, 6. Pedicle, 7. Inferior articular process, 8. Superior articular process, 9. Lower Chest Ribs. All these anatomical regions should be clearly visualized in X-Ray image <sup>(10)</sup>.

Body Mass Index (BMI) values are the key index of the relationship in weight and height of the human beings. BMI is calculated as, weight kg/height m<sup>2</sup>. This is commonly use to surrogate in diagnosis of the obesity and fat distribution. As the fat increases or decreases near or at the lumbar region, on the basis of BMI values calculation patient can consider as fatty/obese or normal patient as shown in Table 1. On the basis of BMI values radiographer can adjust the radiation exposure parameter to the optimum level to achieve the good quality of radiographs also can eliminate the extra radiation absorbed dose to patients <sup>(11, 12)</sup>.

Vasileios I. et al. conducted a study and says that the dose audit is important in the optimization of the patient's radiation protection in diagnostic. In this study, the effect of body mass index (BMI) on radiation dose were calculated. Total 1869 adult patients underwent chest, abdomen, lumbar spine, kidneys and urinary bladder (KUB) and pelvis radiography. All procedures was done for both, overweight and obese patients and compared with normal patients through Mann-Whitney test ( $p < 0.0001$ ) and were found significantly positive relationship between patient body size and exposure factor <sup>(13)</sup>.

Patrick Knott, et al. performed a study on reducing the X-Rays exposure in pediatric patient's scoliosis patients. In this study, such significant advance changes have been made in current diagnostic techniques. In general, adolescents are exposed to less radiation dose for radiographic imaging, and

proved that newer imaging techniques are able to decrease the amount of radiation exposure. Researcher well explained that it should be noted the rates of cancer secondary to primary radiation exposure are not specific in scoliosis patients. Dosages for the spine radiograph were reduced from 1/6<sup>th</sup> to 1/9<sup>th</sup> from the standard amount of radiation dose. By following the standard exposure chart as suggested by researcher<sup>(9)</sup>, the radiation dose to patient in higher BMI (Pre-obese and obese) vales, can be minimized by 30-40% without compromise the quality, contrast and resolution of radiographic images<sup>(14)</sup>.

Need of this study- In routine X-Ray procedures, maximum number of patients underwent for spine radiography and took high radiation dose exposure. In which some of them also get repeated exam due to the lack of optimum radiation exposure or poor image quality radiograph and if not repeated then radiologist need to compromised with the poor image quality radiograph and diagnosis has to made for patient. To optimize the radiation dose and improve the image quality of spine radiograph, some bull's eye technique is required. No any study has been yet published in "India" on spine radiograph with consideration of BMI values before performing the examination. BMI values may provide an idea to choose appropriate radiation exposure factors, which can be help to radiographer to minimize the amount of radiation dose to patient.

**Aim:** To evaluate the role of BMI values before each L. S. spine radiograph and to choose the optimum radiation exposure factors without compromised the radiographic image quality.

## Method And Material

The data of BMI values of each patient's and radiation exposure values like mAs & kVp were collected with the help of radiographer in the department. This study was based on the observation analysis of BMI values with radiation exposure parameters like mAs & kVp. As per pre-decided selection criteria, the patients only from Out Patient Department (OPD) with clinical history of lower back pain were added in this study. And trauma patients, patient form in-patient department (IPD), pediatric, unwilling patient and pregnant patient were excluded from this study. Each set of data after selection criteria was collected on the single stationary 600 mA Allenger X-Ray equipment.

Total 60 patient's data have been collected after the exclusion criteria out of 60, total 40 patients were added in this study. Out of forty patients, 26 were female and 14 male patients (Figure-2) were added. The data was collected in a proper manner by the researcher only. Measurement of BMI values & radiation exposure factor values were taken.

Total number of patients in highest and lowest BMI range, the lowest value of BMI was observed 19.0 which is under Normal range and highest value of BMI was observed 32.5 which is under obese-1 category as shown in Figure 3.

After the compilation of data set from minimum to maximum BMI values (Figure 3), the data were further segregated in different aspect to see the various pattens like-

Number of patients in each BMI categories, 9 patients were found under normal range, 9 patients were found under overweight, 10 patients were found under Pre-obese, 7 patients were found under Pre-obese 1 and in the obese-1 category 5 patients were found as shown in Figure 4.

Number of male and females in each BMI category, 2 male and 7 females patients were found under normal, 3 male and 6 females patients were found under overweight, 7 male and 3 female patients were under Pre-obese, 2 male and 5 female patients were under Pre-obese 1, no any male patient in last category described as obese-1 this category have only 5 female patients as shown in Figure 5.

Observation report of various BMI values correlation with radiation exposure factor mAs & kVp is shown in Table 2.

The minimum and maximum radiation exposure factors (kVp & mAs) was used for the L. S. Spine Anterior-Posterior radiograph in different BMI categories. Whereas mAs range was from 30 to 100 and kVp range was from 65 to 92 were used in different BMI categories patients as shown in Figure 6.

The minimum and maximum exposure factors (kVp & mAs) used for the L. S. Spine Lateral view radiograph in different BMI categories. Where mAs range was from 50 to 150 and kVp range was from 70 to 96 in different BMI categories as shown in Figure 7.

Recommended and purposed systematic mAs & kVp values as per different BMI categories are shown in figure 8 & 9.

## Result

Out of forty patients 65% were male and 35% were female those underwent the X-Ray L. S. Spine AP & Lateral were added in this study. After that patient's data set further distributed in different categories as explain in method and material. In different BMI category, the amount of radiation exposure factor is different and the values are: in normal BMI, the minimum values of radiation exposure factors were 30 mAs & 70 kVp. and maximum were 38 mAs & 75 kVp in antero-posterior (AP) radiograph and in the lateral radiograph, minimum values of radiation exposure factors 52 mAs & 70 kVp and maximum 58 mAs & 76 kVp were found optimum with good quality of anatomical details.

In overweight of BMI, the minimum value of radiation exposure factors 40 mAs & 70 kVp and maximum values 46 mAs & 78 kVp in AP radiograph, and in lateral radiograph minimum 72 mAs and 75 kVp and maximum 86 mAs and 80 kVp were also found optimum with good anatomical details.

In under Pre-obese of BMI, the minimum values of radiation exposure factors 50 mAs & 60 kVp and maximum 100 mAs and 88 kVp in AP radiograph, and in lateral minimum 80 mAs & 70 kVp and maximum 130 mAs & 91 kVp were found satisfactory with normal image quality.

In under sub category of Pre-obese (PO1) BMI i.e. Pre-obese1, the minimum values of radiation exposure factors 40 mAs & 70 kVp and maximum 90 mAs and 92 kVp in AP radiograph, and in lateral radiograph

minimum 70 mAs & 69 kVp and maximum 150 mAs & 96 kVp were not found up to the mark with low anatomical details.

In the sub category of Obese BMI, i.e. Obese1, the minimum values of radiation exposure factors 50 mAs & 75 kVp and maximum 85 mAs & 90 kVp in AP radiograph, and in lateral radiograph minimum 100 mAs & 80 kVp and maximum 150 mAs & 85 kVp were also not found satisfactory with low anatomical details.

In the result, the exposure factors were used in first two categories i.e. normal BMI and overweight BMI were found optimum with good anatomical details and good quality radiographs. But in rest three BMI categories i.e Pre-Obese, Pre-obese 1 and Obese, the radiation exposure factors were not found appropriate in different BMI values/category.

After the correlation of BMI values with radiation exposure factor mAs & kVp values, new systematic optimum radiation exposure factors were calculated by simple mathematical formula. New radiation exposure factors mAs & kVp values are purposed for the L. S. Spine Anterior-Posterior & Lateral radiographs. In which different BMI categories consist of their own minimum and maximum values of mAs & kVp are shown in Table 3 & 4.

## Discussion

In this study role of Body Mass Index (BMI) in Lumbar Sacrum (L.S) Spine Anterior-posterior (AP) and Lateral radiography, radiation factor was calculated before each examination. This study was inspired by various researches conducted by different authors in which like S. Reena, S. Sunil Dutt, Ajay Chaubey, et al. described the screen-film system is replaced by computed radiography system by recording the images of the patients during X-Rays radiography examinations. The change in imaging system was required and to reestablishment of the institutional diagnostic reference levels (DRLs), different types of X-Rays procedures was conducted at the hospital. For the same purpose, patient specific parameters like age, height, weight, body mass index (BMI), object to image distance (OID) and machine specific parameters like kVp, mAs, distance and collimation sizes were recorded. Total 1875 patients under 21 different types of X-Rays examinations was added in this study to estimating the entrance skin dose (ESD) <sup>(15,16)</sup>. In this study radiation exposure factors were observed with BMI values of each patient to find out the appropriate range of exposure in each BMI category. Study recommends that BMI values are important indicator to select or calculate the radiation exposure factors before each procedure. Because as the BMI values increases tissue variation in region of interest changes. Hence it is better to measure BMI values before performing radiation exposure which helps to get better quality radiographs without losing the anatomical details, image resolution and contrast.

Pagan L, et. al., Aldrich J et. al., Faulkner K et.al., conducted study on the patient radiation absorbed dose in digital projection radiography with reference to optimization of radiation absorbed dose, the role of image quality with dose and measurement of patient dose in various diagnostic radiology procedures respectively. These three studies well explain the role of optimum radiation dose with image quality and

requirement of minimizing the amount radiation dose on the basis of radiation exposure factors selection. As understood the amount radiation absorbed dose varies from patient to patient as well as the area of interest under the X-Ray examination. Responsibility of healthcare professionals are to reduce the amount of radiation dose for patient in all possible manner<sup>(16,17)</sup>. Priority is to achieve the best quality radiograph to make radiologist job easy and best diagnosis for the patient. Radiographer can do his/her job easily with the minimum possible exposure factors which can gave optimum radiograph quality and decrease the unwanted radiation to the patient<sup>(18,19)</sup>.

## Conclusion

The study concludes that blind selection of radiation exposure factors (mAs & kVp) for each X-Ray procedure is unprofessional behavior of radiographer. Appropriate radiation exposure factor mAs & kVp) selection, the amount of radiation dose for can be reduced by 20-30% without compromising the radiographic image quality.

## Recommendations

1. Radiographers must follow the term ALARA & TDS principal.
2. Calculation of BMI values should take under consideration before L.S Spine AP & Lateral radiography.
3. Manipulation in radiation exposing factors mAs & kVp must done as per the need of different BMI values/categories
4. New radiation exposure factor mAs & kVp values for L.S Spine AP & Lateral are purposed as per different BMI categories shown in table 3 & 4.

## Abbreviations

- **ALARA**- As Low As Reasonably Achievable
- **AP**- Anterio-Posterior
- **BMI**- Body Mass Index
- **CT**- Computed Tomography
- **DRL** - Diagnostic Reference Levels
- **kVp**- Kilo Voltage Peak
- **LAT**- Lateral
- **S.**- Lumbar Sacrum
- **mAs**- Milli Ampere Second
- **OID**- Object to Image Distance
- **P01**- Pre-Obese 1

- **TDS- Time Distance & Shielding**

## Declarations

**Ethics approval and consent to participate** – Ethical approval was taken from the central institutional committee of SGT University Hospital & Research Institute and all methods were performed according to guidelines and regulations provided by central committee under "Ethics approval and consent to participate" section. Approved Informed consent forms were obtained from each participant.

**Consent for publication**- Hereby, all author agrees to publish this study and give consent for the availability of the data set.

**Availability of data and materials**- Radiation dose technical factors (mAs & kVp) & BMI values data-set carefully taken and recorded by the researcher. The datasets generated and/or analysed during the current study are available in the MS Excel. Data can also be shared by the corresponding author on reasonable request.

**Competing financial and/or non-financial interests** - No, I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

**Funding**- The authors neither received nor wants any type of commercial support in the form of either compensation or financial support for the study or for personal interest. This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Authors' contributions**- Virmani Nitish (3) and Yadav Kripanand (1) conception, design of the work, the data acquisition, analysis, and interpretation of the data. Navreet Boora (2) & BB Sharma (4) contributed in commenting on the paper and have approved the final version. All authors reviewed the manuscript.

**Acknowledgements**- We are thankful to Mr. Mohit Deswal & Mr. Vaibhav M.Sc Fellows for CT scan procedures and data compiling.

### Conflict of Interest

No conflict of interest.

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## Tables

**Table 1. Showing the specimen images and range of BMI values according to categories prescribed by Asian Criteria.**

Nutritional status based on the WHO and "Asian criteria" values		
Nutritional Status	WHO criteria BMI cut-off	"Asian criteria" BMI cut-off
Underweight	<18.5	<18.5
Normal	18.5-24.9	18.5 – 22.9
Overweight	25-29.9	23 – 24.9
Pre-Obese	-	25.0 - 27.5
Pre-Obese 1	More than 30	27.6 – 29.7
Obese1	30 – 40	30 - 40

**Table 2. Radiation exposure factors of various BMI categories**

BMI Categories		mAs	kVp
<b>Normal</b>	<b>AP</b>	30- 35	65-70
	<b>Lat</b>	50-55	70-75
<b>Over weight</b>	<b>AP</b>	40-45	70-75
	<b>LAT</b>	55-60	75-80
<b>Pre obese</b>	<b>AP</b>	80	80
	<b>LAT</b>	108	86
<b>Pre obese 1</b>	<b>AP</b>	74	78
	<b>LAT</b>	110	88
<b>Obese 1</b>	<b>AP</b>	75	80
	<b>LAT</b>	120	84

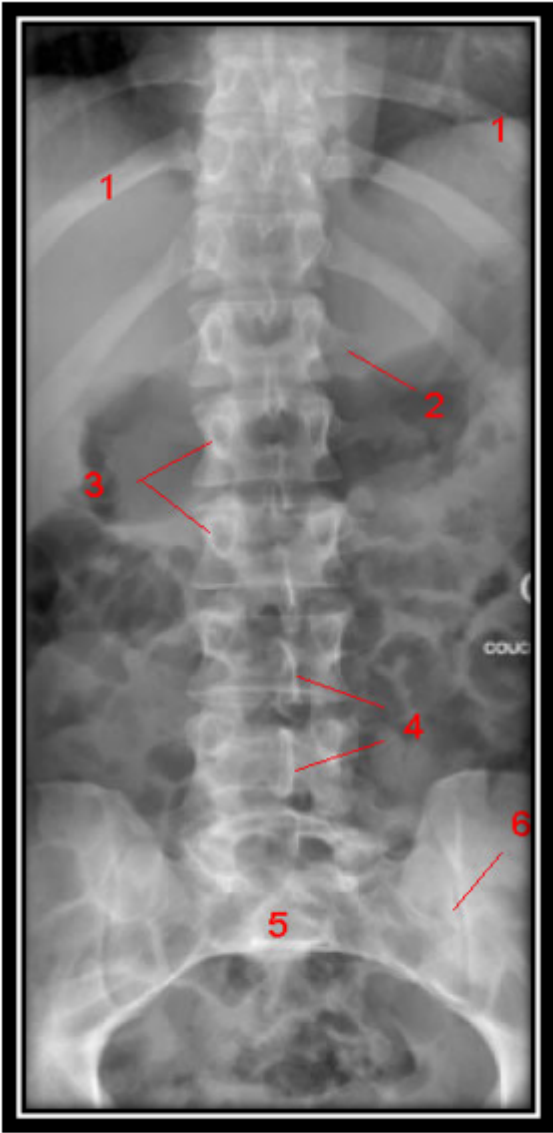
**Table 3 Purposed radiation exposure factors for L.S. Spine Antero-Posterior view**

<b>Radiation Factors</b>	<b>Minimum mAs</b>	<b>Minimum kVp</b>	<b>Maximum mAs</b>	<b>Maximum</b>
<b>BMI Categories</b>				<b>kVp</b>
<b>NORMAL</b>	30	65	35	70
<b>OVER WEIGHT</b>	40	70	45	75
<b>PRE-OBESE</b>	50	75	55	80
<b>PRE-OBESE 1</b>	55	80	60	85
<b>OBESE 1</b>	75	100	80	100

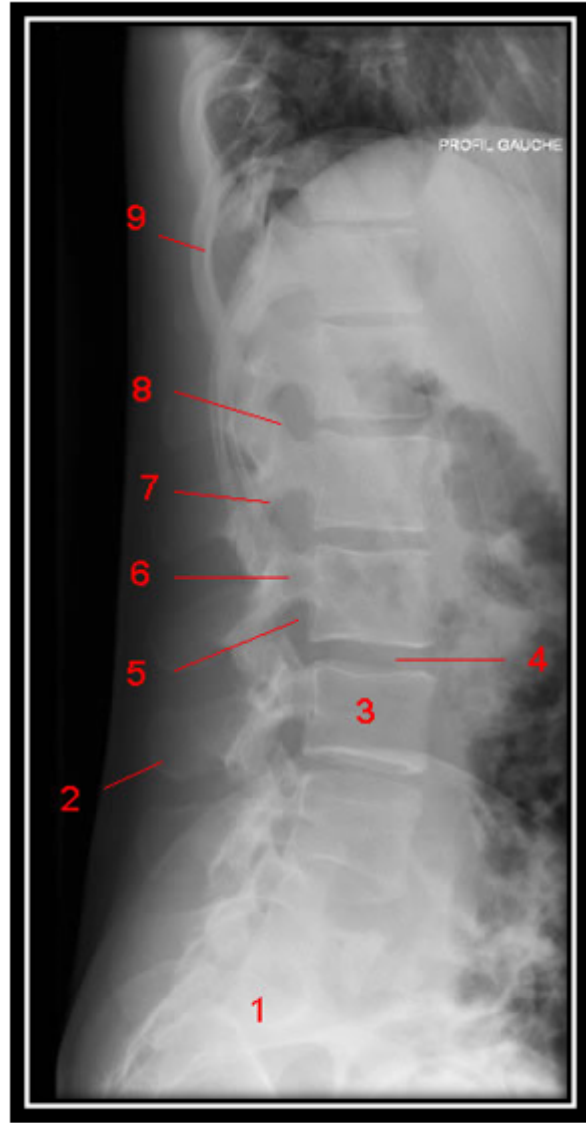
**Table 4 Purposed radiation exposure factors for L.S. Spine Lateral view**

<b>Radiation Factors</b>	<b>Minimum</b>	<b>Minimum</b>	<b>Maximum</b>	<b>Maximum</b>
<b>BMI Categories</b>	<b>mAs</b>	<b>kVp</b>	<b>mAs</b>	<b>kVp</b>
<b>NORMAL</b>	50	70	55	75
<b>OVER WEIGHT</b>	55	75	60	80
<b>PRE-OBESE</b>	65	80	70	85
<b>PRE-OBESE 1</b>	70	85	75	90
<b>OBESE 1</b>	80	100	90	100

## Figures



**1a**



**1b**

**Figure 1**

1a and 1b showing the common anatomical areas need to be visualized clearly in L.S. Spine radiography.

# Total No. of Patients

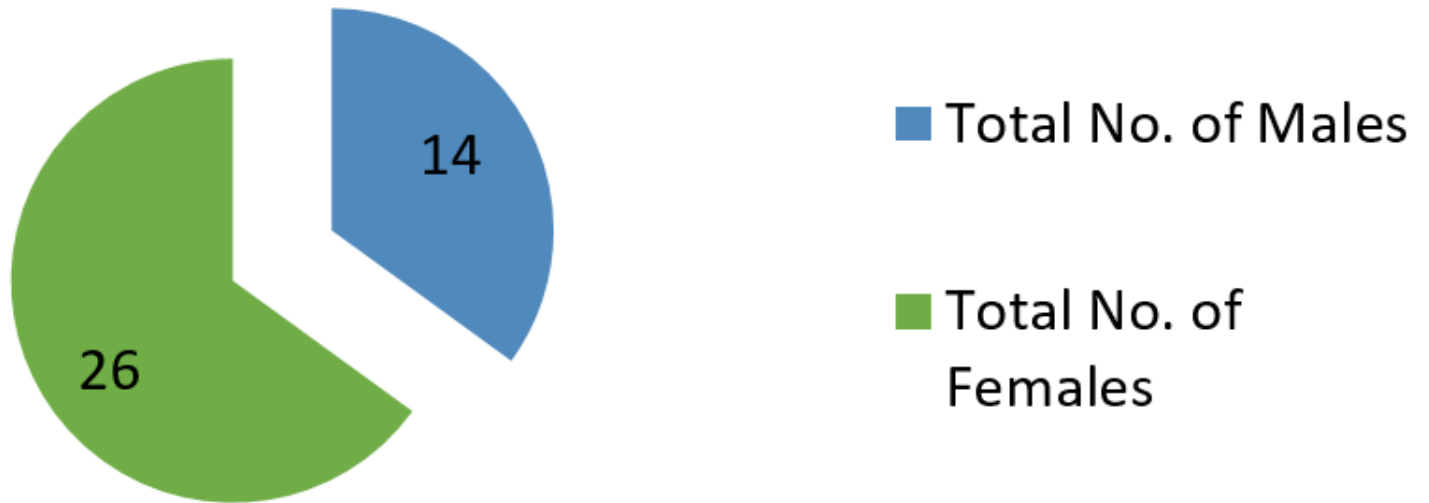
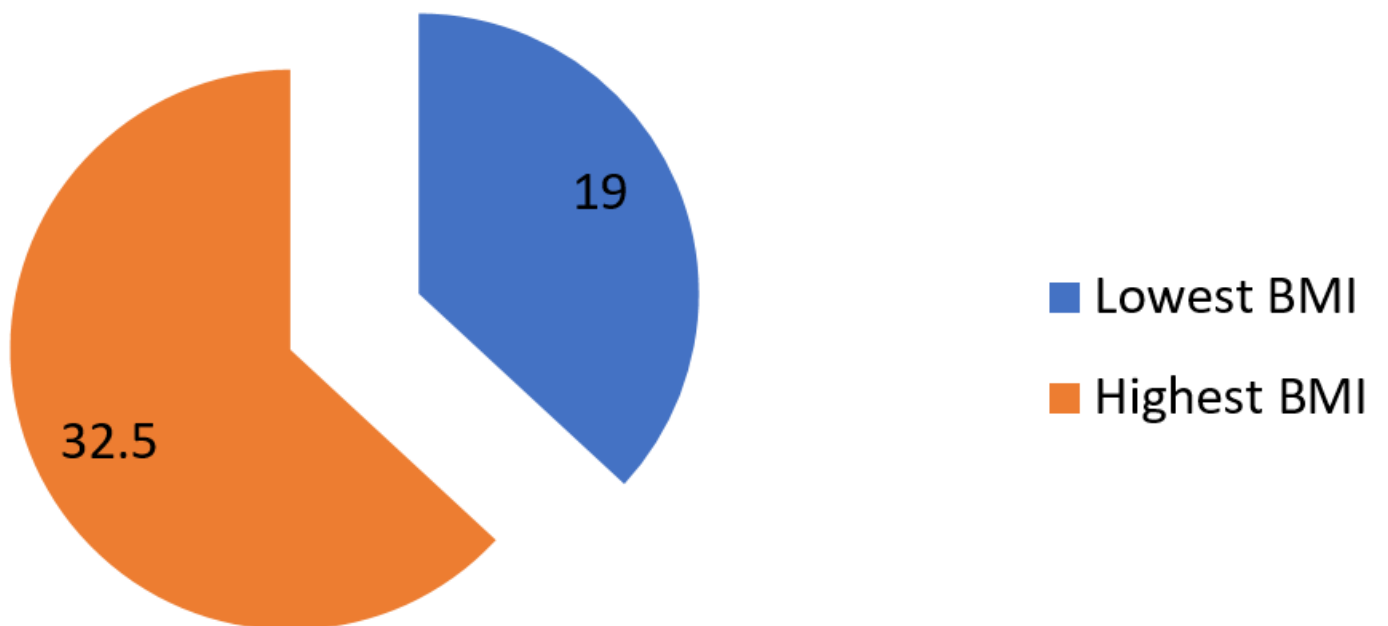


Figure 2

Represents the demographic data of total 40 patients include 14 male and 26 female patients in the study for sample collection.

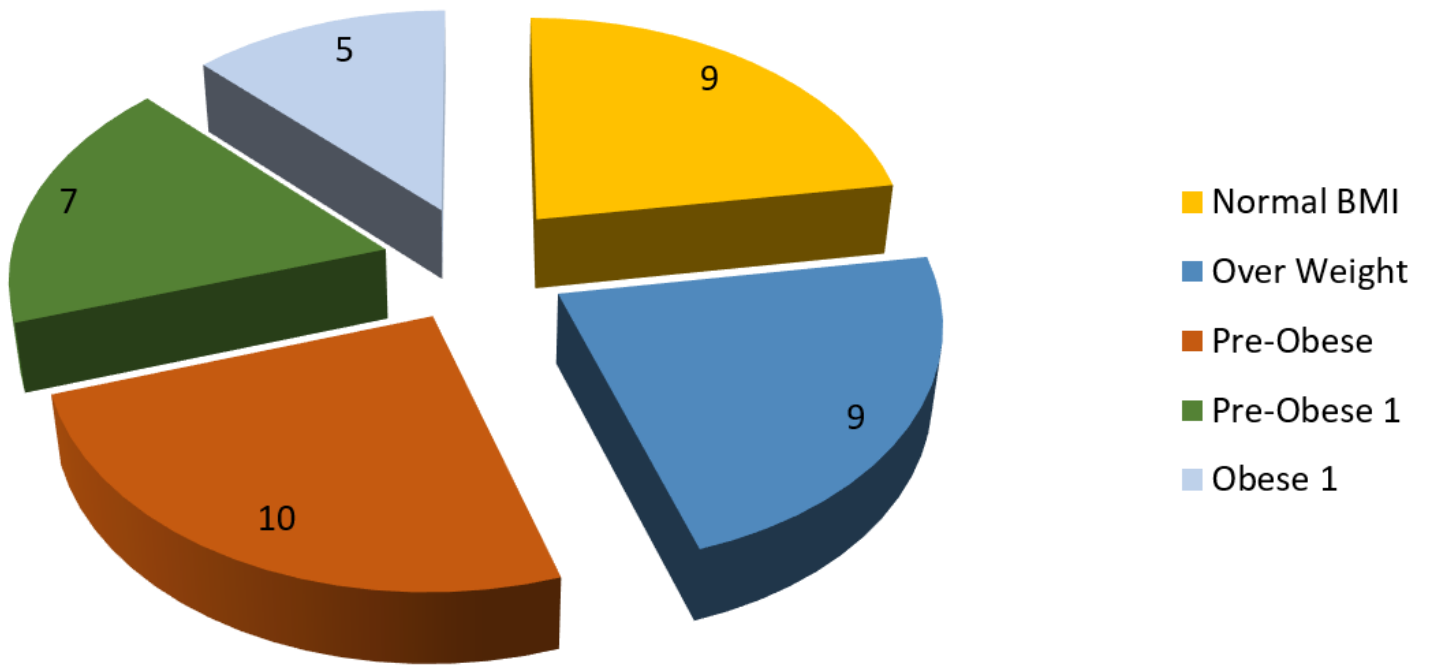
# BMI RANGE



**Figure 3**

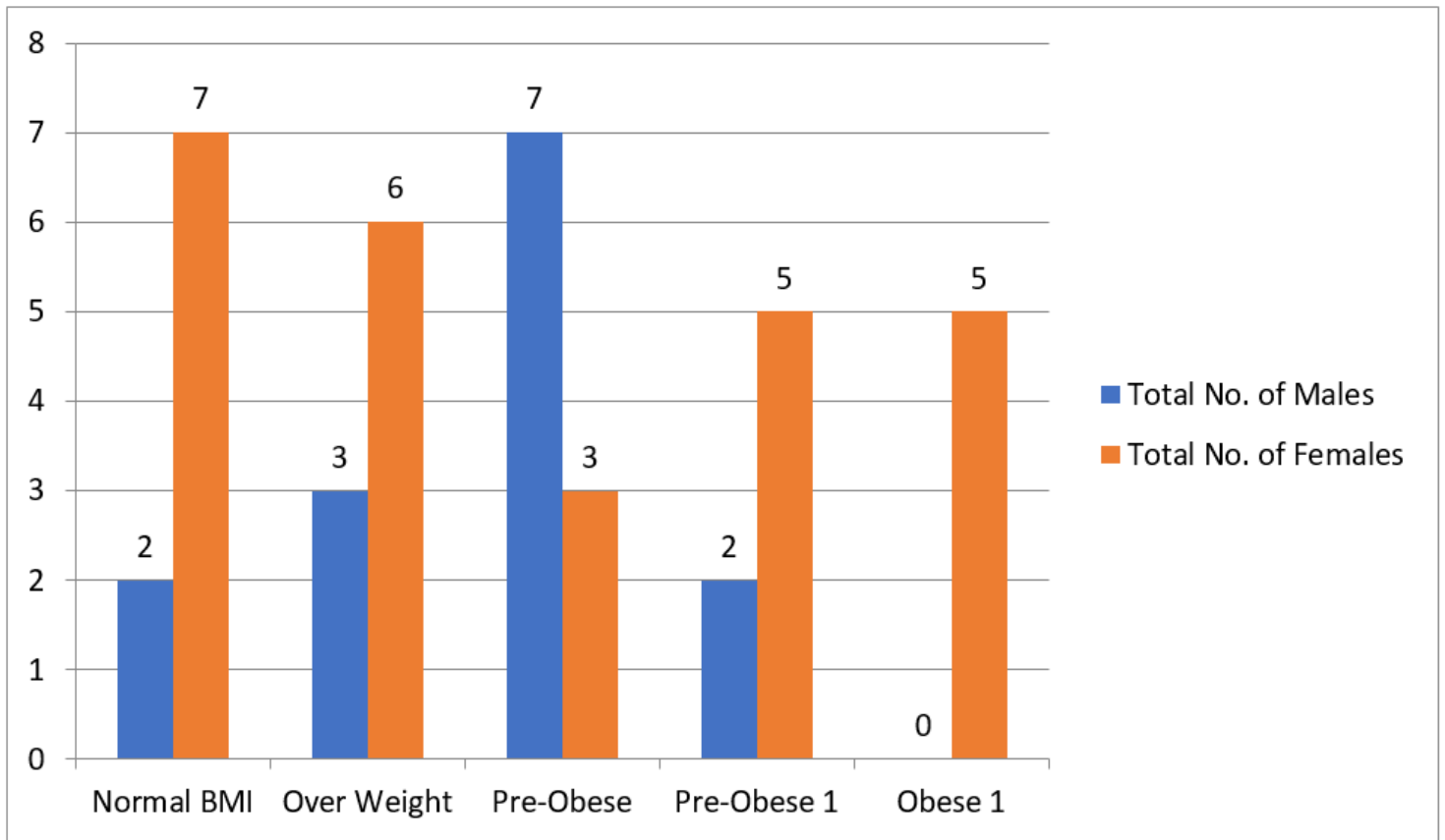
Represent the data of lowest and highest BMI range of patient included this study.

**TOTAL PATIENTS**



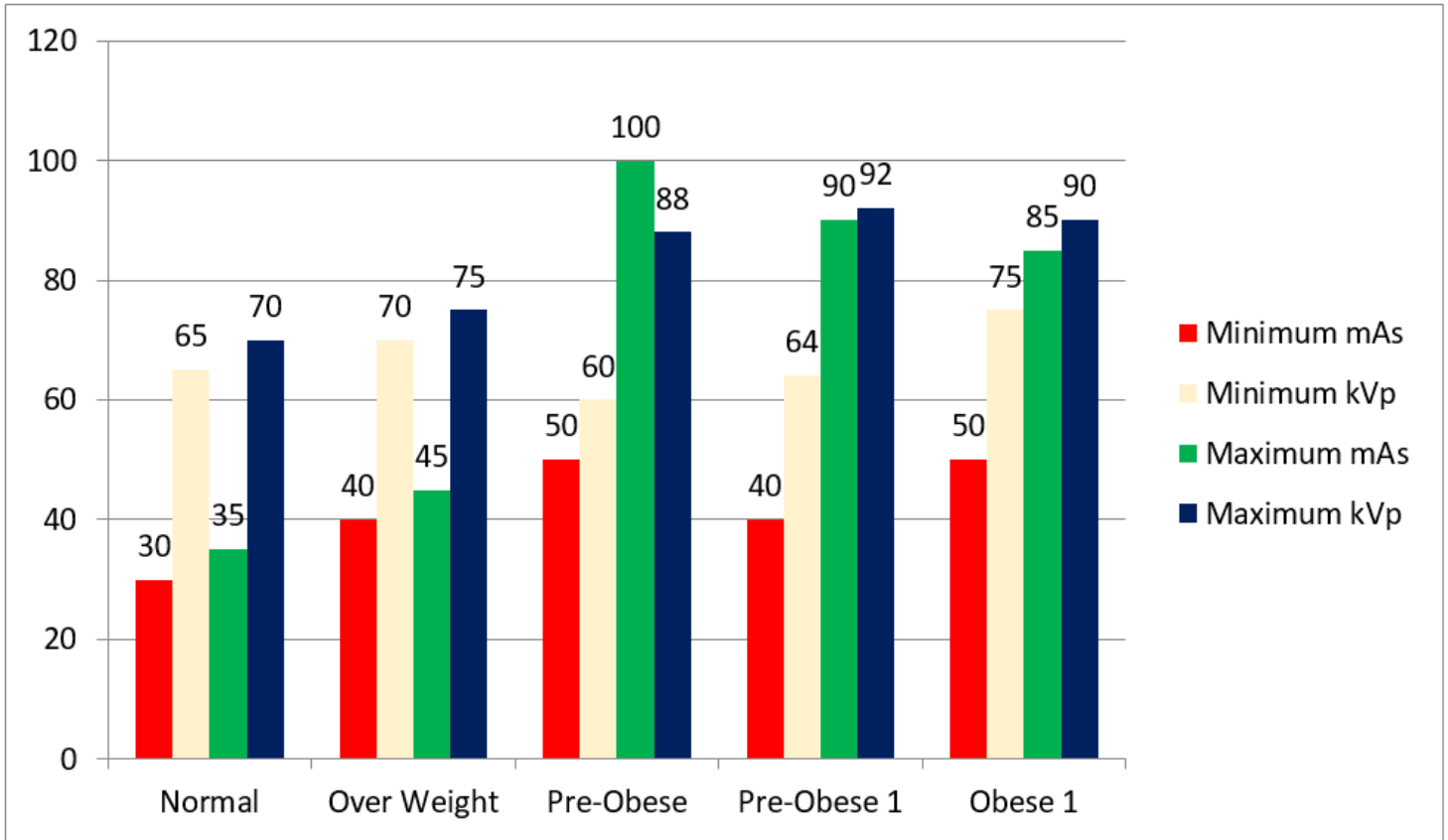
**Figure 4**

Represents the data of total number of patients in each BMI category



**Figure 5**

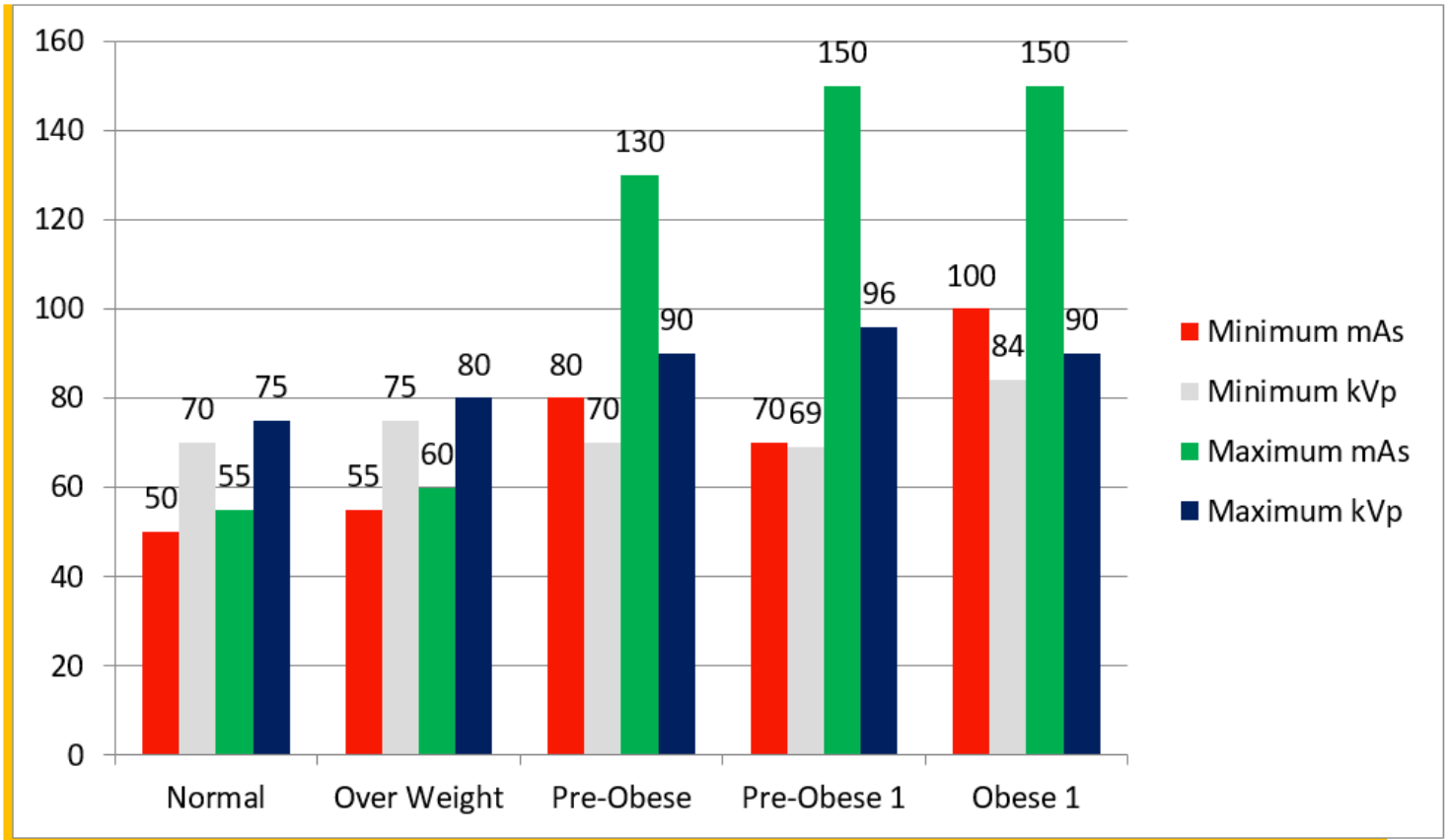
Representation of data with number of male and female patients as per each BMI category.



**Figure 6**

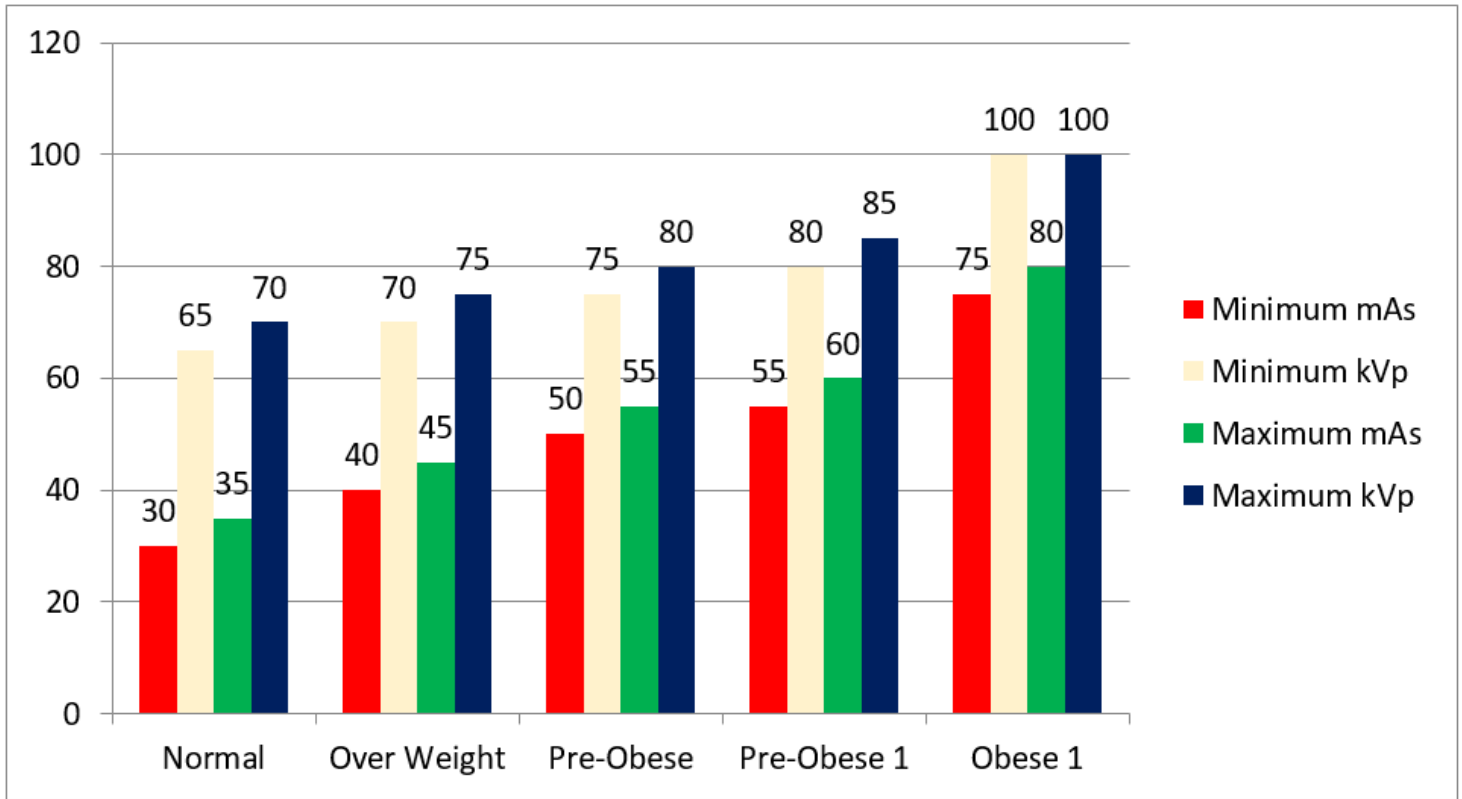
Represent the variation in radiation exposure factors in different BMI categories for the Anterior-Posterior view of L.S Spine.





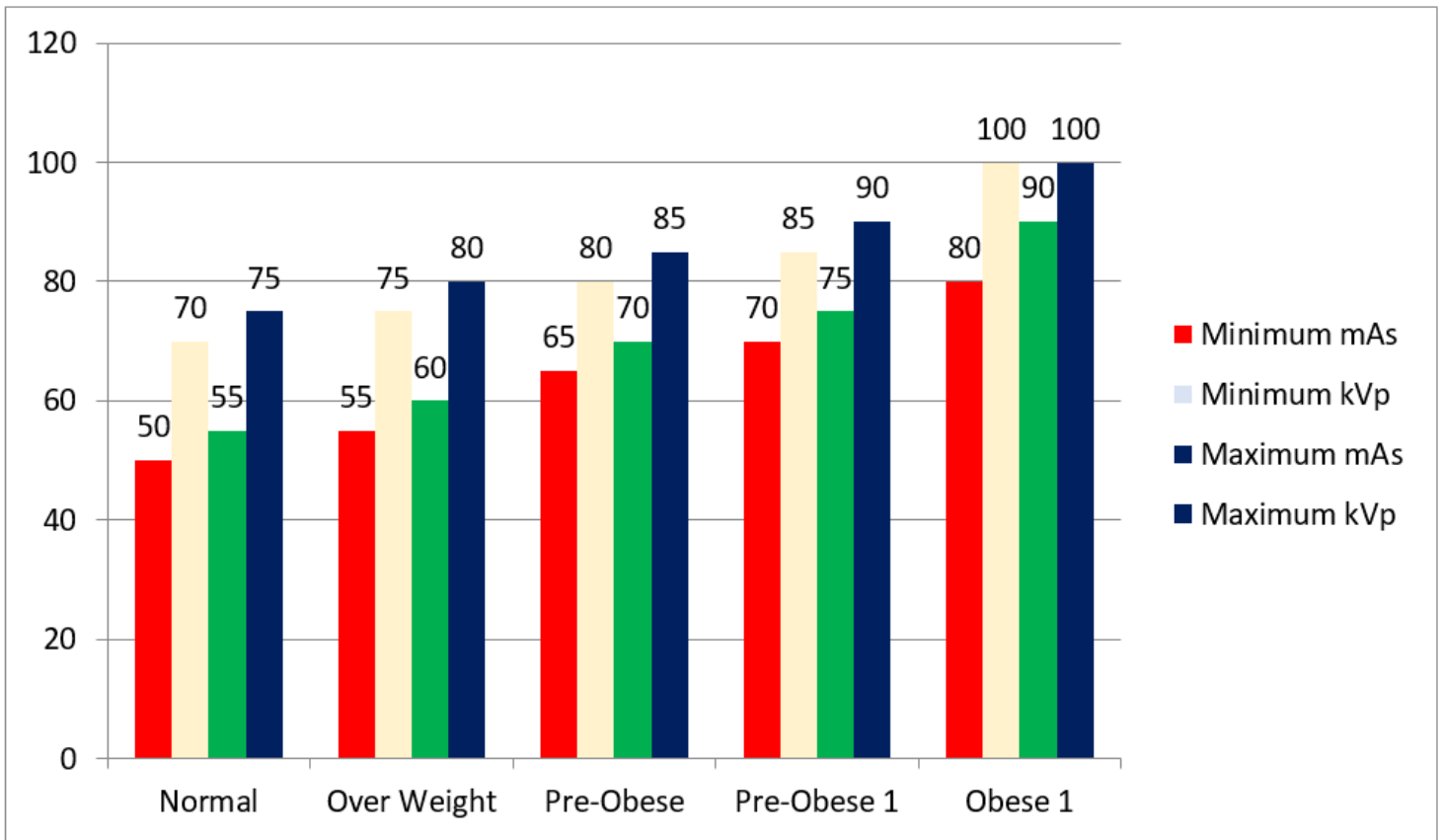
**Figure 7**

Represents variation of radiation exposure factors in different BMI category for the Lateral view of L.S Spine.



**Figure 8**

Represents the minimum & maximum mAs and kVp in each BMI category of radiography of L.S Spine AP view



**Figure 9**

Represents the minimum & maximum mAs and kVp in each BMI category of radiography of L.S Spine lateral view