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The Study of Mean Glandular Dose in Mammography in Yazd and the Factors Affecting It

Backgrounds/Objective: The objective of this study was to determine the mean glandular dose (MGD) resulting from mammography examinations in Yazd, southeastern Iran and to identify the factors affecting it.

Patients and Methods: This survey was conducted during May to December 2005 to estimate the MGD for women undergoing mammography and to report the distribution of dose, compressed breast thickness, glandular tissue content, and mammography technique used. The clinical data were collected from 946 mammograms taken from 246 women who were referred to four mammography centers. The mammography instruments in these centers were four modern units with a molybdenum anode and either molybdenum or rhodium filter. The exposure conditions of each mammogram were recorded. The breast glandular content of each mammogram was estimated by a radiologist. The MGD was calculated based on measuring the normalized entrance skin dose (ESD) in air, Half Value Layer (HVL), kVp, mAs, breast thickness and glandular content. HVL, kVp and ESD were measured by a solid-state detector. The analytical method of Sobol et al. was used for calculation of MGD.

Results: The mean±SD MGD per film was 1.2±0.6 mGy for craniocaudal and 1.63±0.9 mGy for mediolateral oblique views. The mean±SD MGD per woman was 5.57±3.1 mGy. A positive correlation was found between the beam HVL with MGD (r=0.38) and the breast thickness with MGD (r=0.5).

Conclusion: The mean±SD MGD per film of 1.42±0.8 mGy in present study was lower than most of similar reports. However, the mean MGD per woman was higher than that in other studies.

Keywords: health physics, radiation protection, mammography, quality control

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Introduction

In any radiographic procedure, it is imperative that the radiation dose is as low as reasonably practicable, while maintaining an adequate image quality. This is particularly important in radiography of sensitive organs such as breast and in screening programs where the exposed population is asymptomatic. It is generally accepted that the glandular tissue of breast is the most radiation-sensitive tissue.[1] Therefore, the suggestion that the mean glandular dose (MGD) is the most appropriate dosimetric quantity to predict the risk of radiation-induced carcinogenesis has been widely accepted.[1,2] The two main methods for the assessment of MGD in mammography are the use of a standard breast phantom and patient-based measurements. Standard breast or phantom measurement is utilized to define the MGD limitsand is well suited for quality control assessment and inter-system comparison to ensure that all units are capable of achieving acceptable doses.[3-5] Such measurements, however, do not indicate the actual dose received by the individual woman.[6,7] The primary objective of this study was to determine the MGD during a diagnostic mammography. The second objective was to evaluate the factors affecting MGD, namely half value layer (HVL) of the X-ray beam, compressed breast thickness (CBT), body mass index (BMI), percentage of glandular tissue and patient age. Such data are necessary to formulate recommendations to minimize radiation doses without compromising the image quality, and for the development of national reference doses as recommended by the International Atomic Energy Agency (IAEA).[8, 9]

Patients and Methods

The survey was conducted over six months on 946 mammograms taken from 246 women in Yazd, middle of Iran. The gathered data included automatic exposure control (AEC) mammograms of various views from diagnostic examinations. The mammographies were done by four mammography x-ray units—two Metatronica, Switzerland; and two Alpha RT Instrumentarium, Finland using a molybdenum (Mo) anode and either Mo or rhodium (Rh) filter.

The calculation of the minimum sample size for this study was based on an error level of 5%, an accuracy of 0.3 and a standard error of 1.78, obtained from a pilot study. We used a simple random sampling to select 104 women from a private clinic and 142 referred to three large hospitals of the city—Shahid Sadooghi, Mojibian and Sohadai Kargar. In Yazd, there are only four radiology centers that perform mammography examinations. All images were taken with a grid using the Kodak MinR 2000 screen-film system. All projection views were combined in the analysis, with no distinction between large and small bucky exposures. The exposure technique factors and clinical data of each mammogram were recorded. The radiographic data recorded included the following:

1- Data entered by the technologist (patient name, age, weight and height); the BMI which is a useful classification scheme for the size and shape of woman, was derived from the ratio of weight/height^2.

2- Patient clinical data (CBT and projection view).

3- X-ray generator data (kV_P, the material used for anode and filter, focal spot size).

4- Data related to AEC variables (density selection, chamber position, and post-exposure mAs). Two different AEC modes were available for the technologist to select Auto-time and auto-kV_P. In auto-time mode, the technologist manually sets the tube voltage and filter selections, and the exposure is photo-timed. In auto kV_P mode, the technologist manually sets the filter selection and the unit selects both the tube voltage and exposure time, based on a pre-pulse exposure. In this survey auto-kV_P were selected for all mammography examinations. The radiation output (mGy/mAs) was measured three time for each kV_P by a solid state detector (Mult-O-Meter Unfors, model 535L, Sweden). Moreover, the kV_P value was measured three times for each set up kV_P; the mean of these readings were then recorded. CBT was measured by ruler in the Metatronica unit and was recorded from monitor in Alpha RT unit. The HVLs of each mammography unit were measured for all kV_P values (23 to 30 kV_P with increment of 0.5 kV). The X_{ESE} for each mammogram exposure was calculated from the mAs (that was recorded after the exposure) multiplied by normalize ESE (mGy/mAs). X_{ESE} was then corrected to the actual source-skin distance for each mammogram. The radiologic parameters of the two mammography units are given in Table 1. Almost all units normally used 18×24 cm^2 films; <1% used 24×30 cm^2 cassette. The OD was variable between -4 to +4. The craniocaudal (CC) and mediolateral oblique (MLO) views were included in this study. The CBT was measured by a ruler, four cm from the chest wall, at the distance between the bottom of the compression plate and the table upon which the breast rested.[10, 11]

Half value layer

The measurements of the "half value layer" were made using a calibrated detector (Unfors solid state detector), placed in the X-ray beam in such a position that its center laid on the axis from the tube focus to a point 4 cm from the chest wall edge of the table (the reference point).[12] To reduce the effects of scattered radiation, the beam size was limited to the size of the detector sensitive area using four thin layers of lead that were placed on the compression plate. The compression plate was positioned as far as possible from the detector. For measuring HVL, high purity (99.9%) aluminum (Al) foils were used. The Al foils (0.1–0.4 mm thick) were placed on the top of the compression plate approximately halfway between the tube focus and detector. The detector was positioned on the top of mammography table (HVL is position-dependent).[12] For measurement of HVL, at first, kV_P tube and an adequate focal spot charge (100 mAs) were selected and then the detector was exposed directly. The filters were positioned on the compression device so intercept the whole radiation field. The same tube load (100 mAs) was used and the detector was exposed through each filter. The exposure to the area of the detector was limited (see European Protocol on Dosimetry in Mammography, ISBN 92-827-7289-6).[12] The HVL is then calculated by the following formula:

$$HVL = \frac{X_1 \ln\left(\frac{2Y_2}{Y_0}\right) - X_2 \ln\left(\frac{2Y_1}{Y_0}\right)}{\ln\left(\frac{Y_2}{Y_1}\right)}$$

The direct exposure readings denoted as Y_0 and the exposure readings after x- ray beam interact with Al filter with thicknesses of X_1 and X_2, are Y_1 and Y_2

Radiation dose calculations

Since we did not have access to the Dance conversion factors, for calculation of MGD we used the method of Sobol et al.[13] In this method, data from existing tables of normalized glandular dose in mammography were parameterized to determine the analytical expressions that match tabulated results within known uncertainties. The parameterization was performed for two different target/filter combinations (Mo, Rh) and different breast compositions (adipose and glandular). The analytical expressions provide the normalized glandular dose for any breast compositions within stated ranges of tabulated input parameters (kV_P, HVL, breast thickness and mAs). The maximum different between the tabulated and parameterized data is 1.29%.[13] Analytical expressions are coded to create custom functions that return the normalized glandular dose for the set of input parameters. In this study, a computer program was developed in Visual C for using this analytical method. The breast glandular fraction was estimated from each mammogram by the radiologist. For running this computer program, we must select target and filter material, kV_P, HVL (mm), breast thickness (cm), percent of glandular tissue (0-1) and entrance skin dose (mGy). Then, the program will calculate the MGD. The MGD per woman was the MGDs sum of two views of each breast. [6] The data were analyzed by SPSS 13.0. The regression analysis was used to evaluate the effect of CBT, BMI and age on MGD.

Results

Patient-based MGD

Patient information and technical factors

Table 2 shows some demographic details of patient enrolled into this study. The participants had mean±SD age of 45.8±8.4 (range: 30–78) years, weight of 67.0 ±10.8 kg and height of 156.2±7.4 cm. Distribution of BMI is shown in Figure 1.

MGD and CBT

As shown in Figure 2, the distribution of CBT was symmetrical ranging from 10 to 75 mm for CC and 10 to 95 mm for MLO views. The frequency distribution of MGD per film for CC and MLO views is shown in Figure 3. The descriptive statistics for MGD and CBT for the study samples are summarized in Table3. The

Table 1. Typical characteristics and radiographic parameters of the two mammography units

	Alpha RT Instrumentarium	Metatronica
Focus-film distance (cm)	60.5	64.5
Anode and Target materials	Mo and Mo, Rh	Mo and Mo, Rh
Tube voltage	23–31 (by 0.5 kV step)	24–30 (by o.5 kV step)
HVL (mm Al)	0.33-0.41	0.38–0.42
Mode of operation	Variable kV protocol AEC	Variable kV protocol (AEC)
Film processor	Protec, Champion	Protect.
Processor temperature© and time(s)	37°, 3 min.	36°, 2.5 min.
Screen, Film	Kodak (minR)+ grid, Fuji	Kodak (with grid),
No. of women	152	94

Table 2. Detail of patient information. Data are presented as mean (min-max).

n	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m²)
246	45.8 (30–78)	67.0 (42–98)	156 (118–174)	27.1 (18.6–47.4)

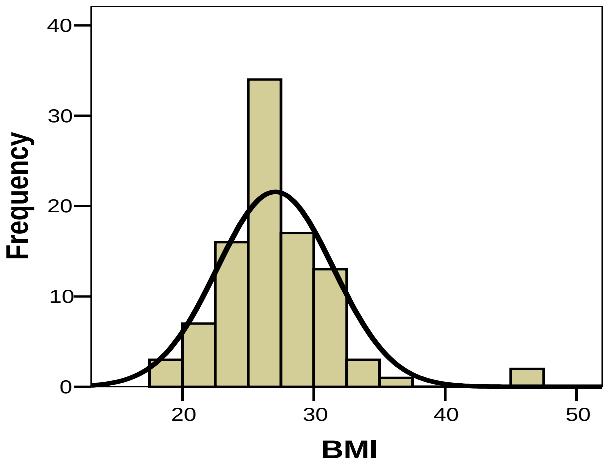

Fig 1. Distribution of patients with respect to their BMI.

two factors affecting MGD, namely HVL and thickness of breast were found to be associated with MGD by regression analysis. Figures 4 and 5 are two samples of these correlations (r =0.5 and r =0.4, regression analysis, power equation). There was no significant association between MGD and BMI (r=0.04) or age (r= 0.1).

Discussion

Patient-based mean glandular dose

The MGD and CBT in Table 3 shows that the mean MGD per film for the MLO (1.63±0.96 mGy) was 29% higher than that for CC view (1.2±0.6 mGy). This could be explained by the presence of pectoral muscle in the oblique view, as was reported by Young et al.[6] The mean±SD CBT for CC and MLO views was 47.6±12.5 and 56.7±13.3 mm, respectively. CBT values for CC and MLO views in the present study were similar to the values recorded by other authors (Table 4).[6,10] In this study, the standard image quality as-

Table 3. Distribution of mean glandular dose (MGD) per woman, MGD per film and compressed breast thickness (CBT). Data are presented as median (25th %ile-75th %ile) and mean (min- max)

MGD per woman (mGy)		view	MGD per film (mGy)		CBT (mm)		HVL (mm)	
Med.	Mean		Med.	Mean	Med.	Mean	Med.	Mean
4.99	5.57 (.6 -19.26)	RCC	1.05(.74-1.58)	1.21 (0.32-3.5)	4.6	47.1 (10-80)	.379	.374
		LCC	1.02(.76-1.6)	1.2 (0.3-3.95)	4.7	46.8 (10-80)	.372	.374
		RMLO	1.41(.92-2.17)	1.67 (0.12-8)	5.6	56.4 (15-85)	.383	.379
		LMLO	1.58(1-2.2)	1.73 (0.12-7.1)	5.5	55.8 (10-100)	.383	.380

Table 4. Comparison of estimated mean glandular dose (MGD) with other studies

Data Source	Conversion Factor	No. of Women	Mean CBT (mm)	Mean Standard Breast MGD (mGy)	Mean MGD per Film (mGy)	Mean MGD per Woman (mGy)
Heggie Australia[7, 14]	Wu	490	52	---	2.26(mean)	4.42 (med)
Eklund Sweden[19]	Rosenstein	1350	50	---	1.25(mean)	4.6(mean)
Moran Spain[9]	Dance	350	52	1.3	1.6(mean)	---
Klein Germany[1]	Klein	1678	55.9	---	1.59(mean)	---
Gentry USA[22]	Wu	4400	CC :45	---	2.07(mean)	----
Burch UK[9]	Dance[15]	4633	CC :52	1.52	1.4(med)	---
Young UK[6]	Dance	8745	MLO :54	1.34	1.7(med)	3.3 (med)
Jamal Malaysia[16]	Wu	300	MLO :44.5	1.23	1.82 (mean)	3.72 (mean)
			CC :37		1.54(mean)	3.37(mean)
Young (NHSBSP)[23]	Dance	8100	MLO :54.3		2.36(mean)	
			CC :51.5	---	1.86(mean)	
Present Study	Sobol	246	45.84		1.45(mean)	
		241	RCC : 47.1		RCC:1.21	
		235	LCC : 46.8		(mean)	5.57(mean)
		239	RMLO : 56.4		LCC :1.2(mean)	
		231	LMLO : 55.8		RMLO:	
					1.67(mean)	
					LMLO:	
					1.73(mean)	

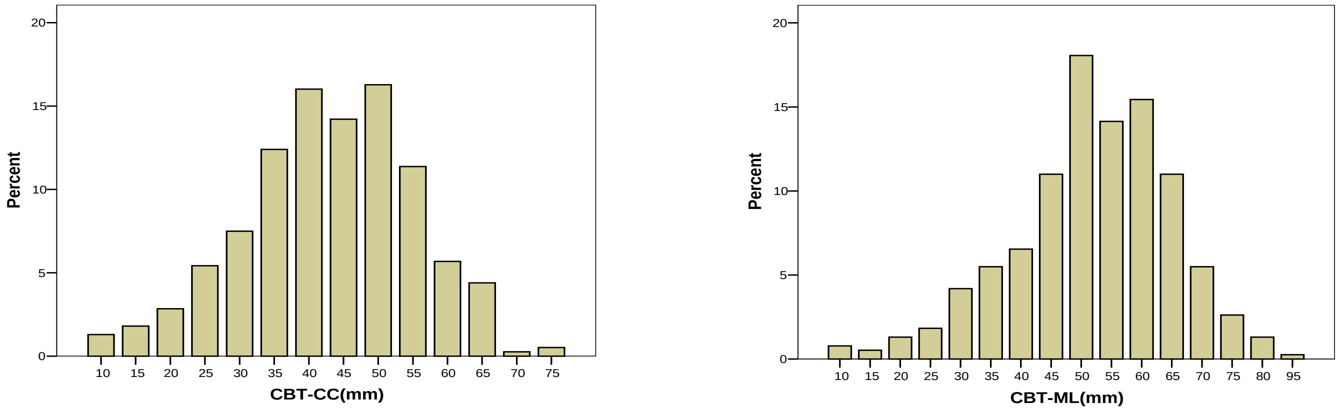

Fig 2. Histogram of the percentage of films as a function of compressed breast thickness (CBT) for (CC) and MLO views.

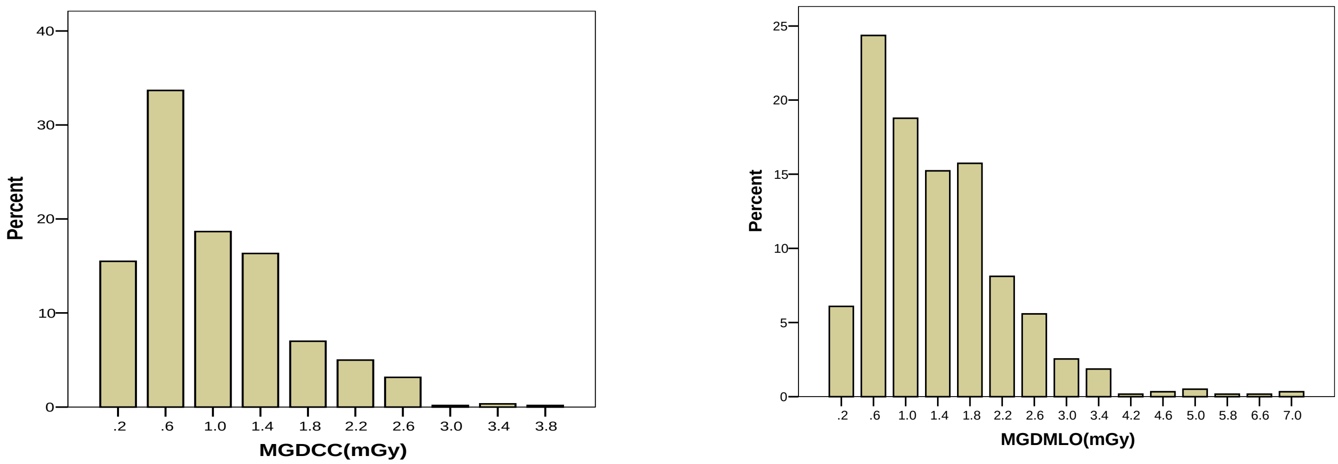

Fig 3. Histogram of the percentage of films as a function of the mean glandular dose (MGD) per film in craniocaudal (CC) and medio-lateral oblique (MLO).

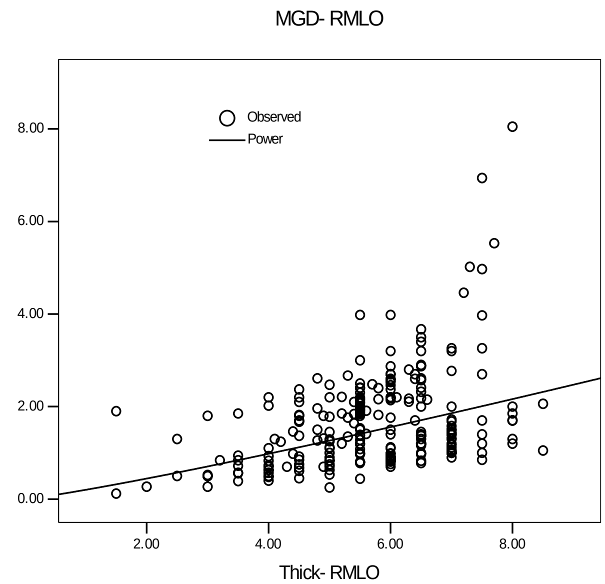

Fig 4. Regression line showing association between the mean glandular dose (MGD) and thickness of breast.

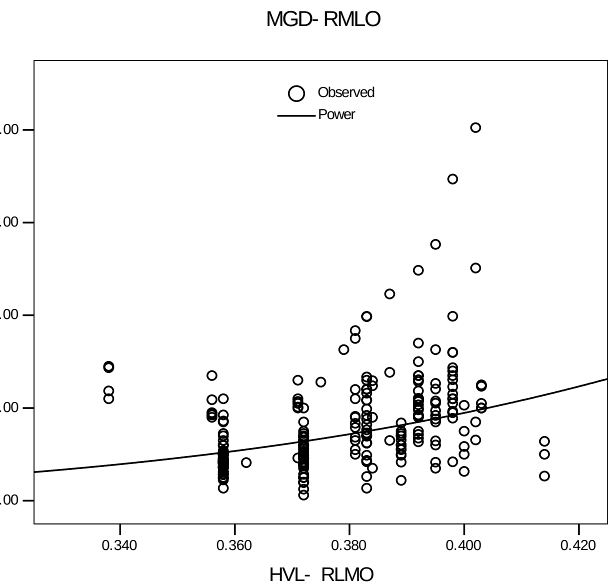

Fig 5. Regression curve showing association between the mean glandular dose (MGD) and HVL.

sessment was not performed; the associated films were just judged to be clinically acceptable. The difference in mean CBT of MLO and CC views is 16.5% (Table 3).

Factors affecting the MGD per woman

As expected, two factors have affecting the MGD per woman, namely HVL and CBT. HVL is an indirect measure of the x-ray energy and influences the amount of energy deposited, while CBT influences the length of x-ray passage through the breast and consequently, the energy absorption.

This highlights the principle that maximizing HVL will maximize MGD. It also indicates that vigorous compression of breast reduces MGD. No significant relationships were observed between MGD per woman and BMI or age; of course, after the age of 54 years, MGD decreases by age (Figure 6). This finding was similar to the results reported by Beckett and Kotre.[2] This could be explained by the fact that the glandular content decreases by age.[7, 14]

Jamal[15] has evaluated MGD for 300 women, and found that the difference of MGD per woman is the result of X-ray tube output, exposure factors, CBT and breast type. This report has given the MGD per film for CC view as 1.44 mGy, comparable with 1.2±0.6 mGy in our study. The difference can partly be explained by the fact that the quality control program had been established in these centers and that all of mammography units were installed in recent years so that they were low dose modern units. Based on UNSCEAR report from two healthcare level II centers in two countries, namely Iran and Turkey, the mean±SD entrance surface dose was 5.5±1.9 mGy before and 4.23±1.2 mGy after establishing a quality control program in Iran.[16] In the reports of Eklund, Young and Burch, MGD estimates were based on the assumption that all breasts have a standard 50:50 adipose:glandular composition (Table 4).[6,9,14] However, Heggie, Klein ,Gentry and we, estimated the breast glandular content by mammogram.[1,7,17] Interestingly, Heggie[7] has reported that if the survey data was reanalyzed assuming a 50:50 adipose:glandular composition, the average MGD per film was reduced from 2.3 mGy to 2.1 mGy, a 5.2%reduction. Similarly, Klein reported that the actual breast composition may cause a variation as much as 15%.[1] In our study, the mean MGD per film, in both views of CC (1.2 mGy) and MLO (1.7 mGy), for the mean CBT of 47 and 56.1 mm, respectively, were significantly (P<0.01) lower than NHSBSP of UK (CC: 1.86 mGy, MLO: 2.36 mGy) and Malaysia (CC: 1.54 mGy, MLO: 1.82 mGy).[17,18] The MGD per film as reported by Eklund (1.25 mGy) was significantly (P<0.001) lower than the values found in our study (1.42mGy).[14] However, the mean MGD per film in our study (1.42 mGy) was significantly (P<0.001) lower than that reported by Klein (1.59 mGy), Dance (1.6 mGy) and Heggie (2.26 mGy).

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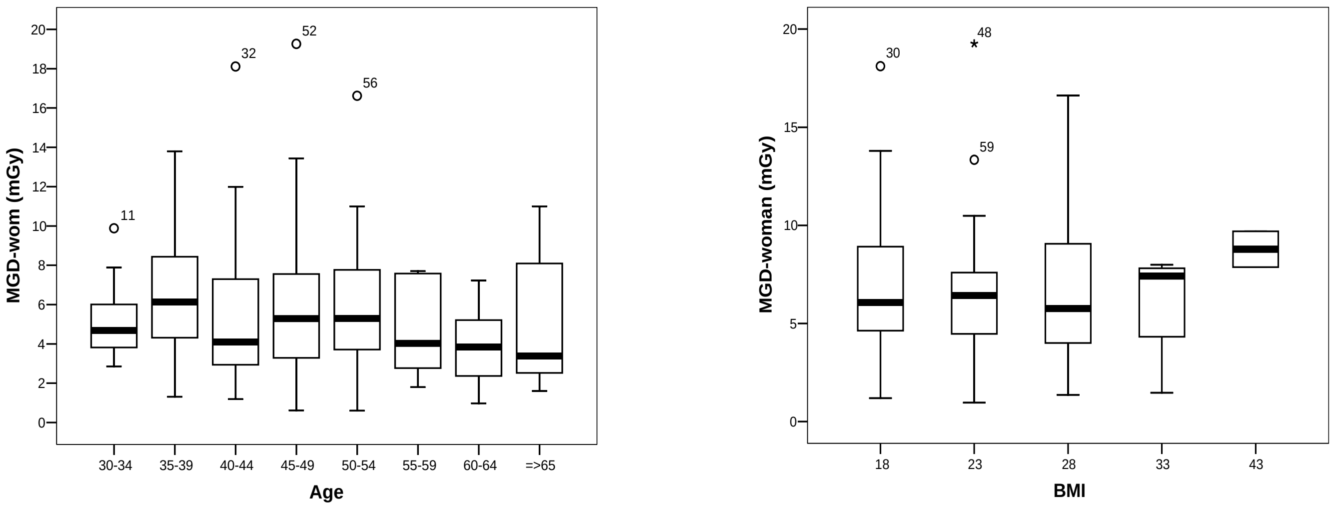

Fig 6. Whisker box-plot showing variations of mean glandular dose (MGD) per woman as a function of age and BMI.

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