Objective Clinical Assessment of Posture Patterns after Implant Breast Augmentation

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Background: An increased weight of the breasts causes several spinal postural alterations that reduce the ability to perform dynamic tasks requiring a stable balance. The effects of the increased weight of the breasts on static posture after implant breast augmentation have not been investigated yet.

Methods: Forty volunteer healthy women were asked to wear different sized breast implants (800, 400, and 300 g) inside a dedicated sports bra for 6½ consecutive hours during their everyday life activities, 1 day for every implant size. Posture changes were assessed with the association of a physiatric clinical examination with a static force platform analysis.

Results: A significant increase in cervical lordosis after the use of 400-g breast implants and upward was demonstrated. This alteration was stable between the 400-g and 800-g breast implants. The 400-g (per breast) implant might therefore be the load threshold that breaks the cervical postural physiologic balance. A significant increase in lumbar lordosis was demonstrated only after the use of the 800-g breast implants. The static force platform assessment demonstrated a worsening of the balance independent from the visual control with the use of 400-g and 800-g implants.

Conclusions: Heavy breast implants proved to induce reversible alterations in the spinal curve, and 400 g is the cutoff for functional physiologic compensation in the short term. Such a weight might be considered the safety limit for the use of breast implants for cosmetic purposes. (*Plast. Reconstr. Surg.* 136: 162e, 2015.)

An increased weight of the breasts causes several spinal postural alterations that reduce the overall ability to perform dynamic tasks requiring stable balance.^{1,2} Dorsal kyphosis and shoulder anterior dislodgement are the key elements of the pathophysiologic figure that in turn tend to increase the lumbar lordosis with

subsequent prominent abdomen.^{3,4} This complex postural alteration tends to directly involve the cervical spine too, with persistent contraction of the cervical spine-stabilizing muscles (trapezius and cervical paravertebral muscles). The sequence of events so far described eventually leads to the so-called pain chain, a continuous spinal pain starting at the lumbar level and extending progressively to the cervical spine, with shoulder irradiation.⁵ Such a clinical figure has been objectively demonstrated in women with breast hypertrophy.⁶

Implant breast augmentation is one of the most popular cosmetic surgical procedures, with an estimated 290,000 procedures performed in 2013 in the United States.⁷ Nevertheless, the effects of the increased weight of the breasts on static posture after implant breast augmentation have not been investigated yet.

The aim of this study was the experimental objective assessment of breast implant-related

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posture alterations in a healthy volunteer female population. Evaluation was carried out with the integration of two different objective methods: a full clinical physiatric examination and a static force platform.

SUBJECTS AND METHODS

The study was carried out in cooperation between the University of Pavia and the Salvatore Maugeri Research and Care Institute. Forty volunteer healthy women were enrolled in the study over a period of 6 months from September of 2013 to February of 2014. The median age was 24 years (interquartile range, 23 to 25 years; minimum, 21 years; maximum, 40 years). The average body mass index was $19.9 \pm 1.4 \text{ kg/m}^2$ (minimum, 17 kg/m^2 ; maximum, 23.7 kg/m^2). The exclusion criteria were current or personal history of back pain of any origin; any orthopedic, vestibular, or neurologic disorder; and alcohol intake within 24 hours before data collection.

Formal informed written consent was obtained from all of the participants. The study complied with the Declaration of Helsinki and was approved by the University of Pavia Ethical Committee.

The study was scheduled into 4 consecutive days. To avoid confounding effects related to time of day, all of the tests scheduled in the trial were carried out at the same time of day (2:30 PM), after 6½ consecutive hours of everyday life activities.

Physiatric Clinical Examination

The participants underwent preliminary anthropometric measurements such as height, weight, shoe size, and submammary thoracic circumference. Body mass index was then extrapolated, computed, and collected.

The volunteers underwent a clinical assessment to measure the distance from the plumbline, fixed at the most prominent point of the dorsal kyphosis, to the spinous processes of the seventh cervical vertebra (C7) and the third lumbar vertebra (L3). The plumbline is used to assess the sagittal and frontal profiles of the spine. The intraobserver repeatability is 1 cm; thus, 1.5 cm is the minimum threshold to be considered significant for data collection in two different visits.⁸ In our study, all of the measurements were performed by the same examiner.

Furthermore, any type of back symptoms, such as neck pain, dorsal pain, lumbar pain, or sense of weight without pain, together with any psychological discomfort were recorded at the

time of any clinical physiatric examination. All of these symptoms were scored using the visual analogue scale.⁹

Static Force Platform Assessment

A single-pedestal static force platform (model ARGO; R.G.M. Medical Devices S.p.A., Genoa, Italy) was used to measure the instantaneous positions of the center of pressure that ensures maintenance of the upright position by balancing the couple produced by the force of weight. The ARGO static force platform has a large platform surface area ($600 \times 600 \text{ mm}$) and allows a high sampling frequency (100 Hz), thus providing a reliable harmonic analysis of sway density parameters even with short measurement times (Fig. 1).

The static force platform provided objective measurement of the following parameters:

- Sway area (in millimeters squared): the extent of the area covered by the center of pressure.
- Confidence ellipse area (in millimeters squared): the smallest elliptical section that includes the 95 percent of the area covered by the center of pressure.
- Anteroposterior distance between the center of the ellipse area and the geometric barycenter of the body (in millimeters).
- Stay time (in seconds): the mean time of permanence of the center of pressure in a given point.

Every subject was assessed on the platform in quiet standing through four different modalities: close parallel feet–open eyes, close parallel feet–closed eyes, slightly spread feet–open eyes, and slightly spread feet–closed eyes. Each assessment

Fig. 1. Static force platform.

Fig. 2. Subject in quiet standing during assessment on the static force platform.

lasted 40 seconds preceded by a 5-second waiting time that allowed the patient to become familiar with the position, thus reducing the adaptation artifacts^{10,11} (Fig. 2).

The implants used in the trial were the 300-, 400-, and 800-cc Round Moderate Plus Profile MemoryGel Implant Sizers by Mentor Corp. (Santa Barbara, Calif.). The breast implants are listed either in cubic centimeters or in grams according to the different manufacturers, with a substantial correspondence between volumes and weights. Therefore, as the exact specific weight of the MemoryGel is unknown, we deliberately approximated it to 1 and considered 1 cc equivalent to 1 g.

On day 1, all of the baseline control assessments were carried out. On days 2, 3, and 4, the participants were asked to wear 800-, 400-, and 300-g breast implants, respectively, inside a dedicated sports bra (Kalenji; OxyLane, Villeneuve d'Ascq, France) for 6½ consecutive hours during their everyday life activities, from 8 AM to 2:30 PM. At the end of this time, they underwent the baseline clinical physiatric examination. The static force platform assessment was deliberately performed only on days 2 and 3, as a preliminary test demonstrated that the differences between the 300-g and 400-g breast implants were below the static force platform sensitivity threshold.

Statistical Analysis

Deviations from the normal distribution were tested by the Shapiro-Wilk test. Quantitative variables deviating from the normal distribution (Shapiro-Wilk test $p < 0.05$) are described in terms of median (25th to 75th percentile) or by mean $\pm$ SD. The Wilcoxon test for paired samples or the

Table 1. Anthropometric Variables

Analyzed Variable	Distribution*	Minimum Value	Maximum Value
Age, yr	24 (23, 25)	21	40
Height, cm	165.8 $\pm$ 6.8	152	182
Weight, kg	55.1 $\pm$ 6.4	42	75
BMI	19.9 $\pm$ 1.4	17.0	23.7
Submammary thoracic circumference, cm	75 (73, 77.62)	67	88
Shoe size (EU)	38 (37, 39)	36	41

BMI, body mass index; EU, European Union.

*Mean $\pm$ SD or median (25th, 75th percentiles) for quantitative variables deviating significantly from the normal distribution ($p < 0.05$, Shapiro-Wilk test).

Friedman test was applied to test for statistically significant differences in terms of quantitative distributions between two or more experimental conditions respectively. The Spearman test was applied to evaluate the correlation between quantitative variables. Delta (Δ) values deriving from the static force parameters have been normalized according to the following formula: $100 \times (\text{post} - \text{baseline}) / \text{baseline}$, where baseline represents the preimplant measurement and post represents the postimplant measurement. $\Delta C7$ and $\Delta L3$ values were estimated as the difference between postprosthesis implant measurements and baseline measurements. The Bonferroni correction was applied to adjust the significance thresholds for multiple testing. Statistical analyses were performed by using R software v3.0.2 (<http://www.r-project.org>).

RESULTS

Descriptive statistics regarding preliminary anthropometric features of the cohort are listed in Table 1. Table 2 lists the clinical measurements at the C7 and L3 levels and the visual analogue scale scores before and after the use of different implant sizes.

In Table 3, variations from baseline in terms of C7 and L3 measurements after the use of the three different prosthesis types are defined as $\Delta C7$ and $\Delta L3$. $\Delta C7$ demonstrated statistically significant increases for both 400-g and 800-g implants ($p < 0.005$, Bonferroni adjusted $p < 0.025$). Similarly, $\Delta L3$ was significantly increased when focusing on measurements deriving from the 800-g implants ($p = 2.98 \times 10^{-5}$, Bonferroni adjusted $p = 0.0002$); whereas the Δ increase observed for 400-g implants was nominally significant, it did not pass multiple testing correction ($p = 0.031$, Bonferroni adjusted $p = 0.188$).

Results from pairwise comparisons showed that $\Delta C7$ values corresponding to the 400-g and

Table 2. C7, L3, and Visual Analogue Scale Score Distributions

Variable	Parameter*	Baseline	Post		
			300 g	400 g	800 g
C7	Median (IQR)	2.6 (2.4, 3.5)	3 (2.5, 3.5)	3.5 (2.9, 4)	3.5 (3, 4.5)
	Minimum	1	1.5	1.5	1.5
	Maximum	7	6.5	5.6	8
L3	Median (IQR)	5.1 (4.9, 5.6)	5 (4.9, 5.5)	5.4 (5, 6)	5.5 (5.2, 6)
	Minimum	3	4	4	4.5
	Maximum	7	7	8	8
VAS score	Median (IQR)	—	1 (0, 3.2)	0.5 (0, 3)	6 (3.7, 7)
	Minimum	—	0	0	0
	Maximum	—	6	8	10

IQR, interquartile range (25th, 75th percentiles); VAS, visual analogue scale; —, not measured.

*Median (interquartile range), and minimum and maximum values of each variable's distribution at baseline measurement and after wearing of different implants.

Table 3. Variations in Terms of C7 and L3 Values before versus after Implant Wearing

Variable Analyzed	Baseline*	Implant Type (g)	Post†	Δ‡	p§
C7	2.65 (2.45, 3.50)	300	3.00 (2.50, 3.50)	0.00 (−0.08, 0.23)	0.763
		400	3.50 (2.95, 4.00)	0.50 (0.00, 1.00)	0.004
		800	3.50 (3.00, 4.50)	0.65 (0.20, 1.00)	2.94×10^{-6} ¶
L3	5.15 (4.95, 5.65)	300	5.00 (4.95, 5.50)	0.00 (−0.43, 0.20)	0.631
		400	5.40 (5.00, 6.05)	0.25 (0.00, 0.50)	0.031¶¶
		800	5.50 (5.20, 6.08)	0.50 (0.00, 1.00)	2.98×10^{-5} ¶¶

*Median (25th, 75th percentile) of the variable's distribution before implant wearing.

†Median (25th, 75th percentile) of the variable's distribution after implant wearing.

‡Median (25th, 75th percentile) of the difference between measurements taken after implant wearing versus before implant wearing.

§The *p* value was derived from pairwise comparisons.

||*p* < 0.017, based on the Bonferroni correction. Multiple testing correction significance threshold was defined based on the number of tests performed for each variable, thus corresponding to $p = 0.05/3 = 0.001$.

¶*p* < 0.05.

800-g implants were significantly greater than those observed after the 300-g implants ($p = 0.006$, Bonferroni adjusted $p = 0.017$; and $p = 7.4 \times 10^{-6}$, Bonferroni adjusted $p = 2.2 \times 10^{-5}$, respectively). No statistically significant difference was observed between $\Delta C7$ values corresponding to 400-g and 800-g implants, suggesting that the impact of the two prostheses types on variations in terms of C7 from baseline measures was similar (median $\Delta C7$ 400 g = 0.50, median $\Delta C7$ 800 g = 0.65; $p > 0.05$).

Analogously, $\Delta L3$ values after wearing 400-g and 800-g implants were significantly greater than those with wearing 300-g implants ($p = 0.003$, Bonferroni adjusted $p = 0.009$; and $p = 1 \times 10^{-5}$, Bonferroni adjusted $p = 3 \times 10^{-5}$, respectively). Even if no statistically significant difference was observed between $\Delta L3$ corresponding to 400-g and 800-g implants, the impact of the two implant types on variations in terms of L3 from baseline increased proportionally to their weight (median $\Delta L3$ 400 g = 0.25, median $\Delta L3$ 800 g = 0.50; $p > 0.05$) (Table 3 and Fig. 3).

No statistically significant correlations were observed between $\Delta C7$ and $\Delta L3$ measurements for the three implants types ($p < 0.10$, $p > 0.05$). These observations suggest that these

two parameters tend to vary independently. Univariate tests demonstrated weak associations between $\Delta C7$ values and height, weight, visual analogue scale score, and symptoms (Table 4).

$\Delta C7$ with the use of 400-g implants correlated negatively with height ($\rho = -0.49$, $p = 0.001$) and weight ($\rho = -0.34$, $p = 0.032$), Bonferroni adjusted $p > 0.05$ in both cases. These results suggest that smaller and weaker subjects tend to have greater $\Delta C7$ values after implant wearing with respect to the rest of the subjects.

$\Delta C7$ with the use of 400-g implants correlated positively with visual analogue scale score ($\rho = 0.34$, $p = 0.030$), total symptoms grading ($\rho = 0.33$, $p = 0.036$), and total symptoms number ($\rho = 0.35$, $p = 0.025$, Bonferroni adjusted $p > 0.05$ in all cases). Globally, a statistically significant difference in terms of visual analogue scale score was observed between the three implant types ($p = 4.45 \times 10^{-13}$). In particular, visual analogue scale score measured at 800 g was significantly greater than at 300 g (median visual analogue scale in 800 g = 6, interquartile range = 3.75 to 7; median visual analogue scale in 300 g = 1, interquartile range = 0 to 3.25; Bonferroni-adjusted $p = 9.20 \times 10^{-7}$) and 400 g (median visual analogue scale in 800 g = 6, interquartile range = 3.75 to 7;

Fig. 3. Comparison of $\Delta C7$ (above) and $\Delta L3$ (below) for the three implant types. Each box plot reports the following distribution parameters (from bottom to top): outlier values, lower nonoutlier bound, 25th percentile, 50th percentile (median value), 75th percentile, upper nonoutlier bound, and outlier measurements. The p value was derived from the Friedman test evaluating the presence of statistically significant differences in terms of $\Delta C7$ and $\Delta L3$ between implant sizes.

median visual analogue scale in 400 g = 0.5, interquartile range = 3.75 to 7; Bonferroni-adjusted $p = 9.20 \times 10^{-7}$), whereas no statistically significant difference in terms of visual analogue scale score was observed between 300-g and 400-g implants (median visual analogue scale in 300 g = 1, interquartile range = 0 to 3.25; median visual analogue scale in 400 g = 0.5, interquartile range = 3.75 to 7; Bonferroni-adjusted $p = 1$). In particular, when focusing on the distribution of $\Delta C7$ by symptom condition, it was possible to observe that individuals with higher C7 values after implant wearing were more likely to be symptomatic. The described trend appears to be proportional to the implant weight, as represented in Figure 4.

None of the identified associations between $\Delta C7$ values and height, weight, visual analogue scale score, and symptoms passed the Bonferroni correction for multiple testing ($p > 0.001$). Within

the set of the analyzed parameters generated by the static force platform, only Δ ellipse area showed relevant variations from baseline measurements after implant wearing.

In the slightly spread feet–closed eyes position, the median Δ value increased proportionally to the implant weight. In particular, a statistically significant increase was observed with the use of 800-g implants ($p = 0.004$, Bonferroni adjusted $p = 0.032$).

In the close parallel feet–open eyes position, the median Δ value increased similarly for both prosthesis types. The increase was significantly greater than 0 for both 400-g and 800-g implants ($p = 0.005$, Bonferroni adjusted $p = 0.040$; and $p = 0.002$, Bonferroni adjusted $p = 0.016$, respectively).

In the close parallel feet–closed eyes position, the median Δ value increased proportionally to the prostheses weight. The observed increases were only nominally significant, because they did not pass the multiple testing correction ($p = 0.028$, Bonferroni adjusted $p > 0.20$ for both variables).

None of the remaining parameters showed statistically significant variations from baseline values (Bonferroni adjusted $p > 0.05$). Results from the analysis of these parameters are listed in Table 5.

DISCUSSION

Although according to the medical literature cosmetic breast prostheses commonly do not exceed 300 cc,¹² market trends sustain an increasing demand for large breast implants.^{13–15} The larger the implant volume, the heavier the weight. To our knowledge, such an implication has not been investigated yet, as other issues (i.e., morphologic changes, breastfeeding, autoimmune and inflammatory diseases, breast cancer, and psychosocial functioning) usually are the object of study in breast augmentation surgery.¹⁶

Many different breast implant types are available on the market, and the most popular are the silicone gel- and saline-filled implants. Because their specific weight may vary slightly according to the different breast implant types, we deliberately decided to approximate it to the saline solution with the 1:1 volume-to-weight equivalence.

Our study involved a sample of young, healthy female volunteers to investigate the spinal postural alterations following the use of breast implants of three different sizes ranging from moderate to large (300, 400, and 800 g). For this purpose, we used the same methods as a previous study that objectively demonstrated the postural benefits of reduction mammoplasty with the original

Table 4. Results from Pairwise Correlation between Quantitative Variables

Variable*	Parameter†	300 g		400 g		800 g	
		Rho	<i>p</i> ‡	Rho	<i>p</i> ‡	Rho	<i>p</i> ‡
Age	ΔC7	-0.10	0.528	-0.07	0.673	0.20	0.216
	ΔL3	0.14	0.386	0.21	0.195	-0.09	0.595
Height	ΔC7	0.12	0.473	-0.49	0.001	0.02	0.920
	ΔL3	-0.15	0.340	-0.08	0.635	0.21	0.194
Weight	ΔC7	0.08	0.640	-0.34	0.032§	-0.07	0.647
	ΔL3	0.07	0.688	-0.07	0.668	0.24	0.129
BMI	ΔC7	-0.09	0.578	0.03	0.837	-0.11	0.486
	ΔL3	0.16	0.327	-0.02	0.891	0.16	0.313
Submammary thoracic circumference	ΔC7	-0.14	0.373	-0.23	0.152	0.03	0.859
	ΔL3	0.15	0.347	0.22	0.167	0.26	0.107
Shoe size	ΔC7	0.14	0.392	-0.27	0.094	0.16	0.335
	ΔL3	-0.16	0.329	-0.11	0.499	0.07	0.656
VAS	ΔC7	-0.12	0.468	0.34	0.030§	0.11	0.515
	ΔL3	-0.08	0.630	0.17	0.291	0.12	0.443
Symptoms (grading)	ΔC7	-0.14	0.397	0.33	0.036§	0.26	0.112
	ΔL3	0.03	0.836	0.16	0.339	0.11	0.482
Total no. of symptoms (score)	ΔC7	-0.14	0.372	0.35	0.025§	0.24	0.131
	ΔL3	0	0.997	0.07	0.689	0.27	0.090

Rho, Spearman correlation coefficient (when both variables were quantitative); BMI, body mass index; VAS, visual analogue scale.

*First variable considered for the comparison.

†Second variable considered for the comparison.

‡The *p* value is derived from the Spearman test (when both variables were quantitative), from the Kruskal-Wallis test (when one of the two variables was quantitative and the second was categorical and characterized by more than two values), or from the Wilcoxon rank-sum test (when one of the two variables was quantitative and the second was categorical and characterized by two values). In the latter two cases, the rho value cannot be estimated and is replaced by an em dash (—).

§*p* < 0.05.

||*p* < 0.001, based on the Bonferroni correction for multiple testing. Multiple testing correction significance threshold was defined based on the number of tests performed for each parameter (the association of ΔC7 and ΔL3 was tested with 12 variables) and repeated for each implant size (300, 400, and 800 g), thus corresponding to *p* = 0.05/(12 × 3) = 0.001.

association of a physiatric clinical examination with a static force platform analysis.²

Our trial was a breast augmentation simulation on a healthy female volunteer population and therefore did not investigate all of the signs and symptoms of true breast hypertrophy.^{17–29}

Indeed, the overall benefits of breast reduction are not related to the posture changes only, but include the correction of the breast ptosis and the bra-related problems also.

The spine profiles were assessed with the plumb-line rather than x-ray films, as we deliberately avoided

Fig. 4. Association between ΔC7 and total number of symptoms. The box plots describe the distribution of ΔC7 according to subjects characterized by increasing number of symptoms. The black horizontal line corresponds to the condition of no variation (*p* value from the Kruskal-Wallis test).

Table 5. Results from the Analysis of Parameters Deriving from the Static Force Platform

Position	Implant Weight (g)	Δ Ellipse Area (mm ²)			Δ AP Distance Ellipse Center-Barycenter (mm)			Δ Sway Area (mm ² /sec)			Δ Stay Time (sec)		
		Median (IQR)*	$p^\dagger$		Median (IQR)*	$p^\dagger$		Median (IQR)*	$p^\dagger$		Median (IQR)*	$p^\dagger$	
SFOE	400	-5.33 (-35.19, 9.1)	0.252		2.38 (-14.83, 14.25)	0.658		-5.52 (-29.15, 10.43)	0.501		0.14 (-16.62, 25.12)	0.227	
	800	-7 (-31.17, 49.94)	0.620		-6.46 (-13.04, 1.85)	0.152		-6.01 (-25.99, 34)	0.701		1.89 (-10.08, 17.15)	0.346	
SFCE	400	4.65 (-27.56, 38.66)	0.460		0 (-9.8, 12.93)	0.425		0.41 (-29.55, 27.08)	0.794		4.96 (-11.65, 27.51)	0.039§	
	800	9.9 (-2.48, 43.66)	0.004		-3.27 (-10.55, 4.61)	0.226		0.14 (-15.44, 19.11)	0.640		-0.32 (-15.72, 22.73)	0.352	
PFOE	400	18.79 (-6.08, 53.05)	0.005		-0.02 (-13.12, 11.15)	0.695		7.66 (0, 38.28)	0.015§		-1.89 (-19.54, 12.27)	0.523	
	800	18.77 (-14.76, 65.05)	0.002		-1.29 (-14.22, 7.5)	0.430		5.72 (-9.5, 35.59)	0.038§		2.24 (-5.73, 18.07)	0.051	
PFCE	400	6.26 (-10.69, 50.81)	0.028§		3.84 (-7.26, 16.96)	0.130		13.3 (-9.83, 25.53)	0.057		3.8 (-11.24, 14.84)	0.391	
	800	8.33 (-11.81, 58.06)	0.028§		-0.61 (-15.9, 12.79)	0.580		4.93 (-15.55, 43.13)	0.059		-7.17 (-15.91, 10.11)	0.450	

AP, anteroposterior; IQR, interquartile range; SFOE, slightly spread feet–open eyes; SFCE, slightly spread feet–closed eyes; PFOE, close parallel feet–open eyes; PFCE, close parallel feet–closed eyes.

*Median Δ value (25th, 75th percentile) of the analyzed parameters [ellipse area in square millimeters, AP distance between the center of the ellipse area and the geometric barycenter of the body (AP distance from the ellipse center to the barycenter) in millimeters, sway area in square millimeters per second, stay time in seconds] according to the different positions and implant weights.

†The p value from the Wilcoxon test evaluating whether the Δ distributions of each parameters were significantly different from 0.

§ $p < 0.05$.

|| $p < 0.006$, based on the Bonferroni correction. Multiple testing correction significance threshold was defined based on the number of tests performed for each parameter in each position (SFOE, SFCE, PFOE, PFCE) and repeated for each implant size (400 and 800 g), thus corresponding to $p = 0.05/(4 \times 2) = 0.006$.

irradiating our young volunteer participants. The plumbline is an effective and reliable alternative to the spine radiograph for assessing the sagittal and frontal profiles of the spine. Moreover, the measurements with this method proved to be easy to perform and low cost compared with other measures that require very expensive dedicated equipment.³⁰

Our study demonstrated the onset of a significant increase in the cervical lordosis after the use of 400-g breast implants and upward. However, such a postural alteration proved to be stable between the 400- and 800-g breast implants. Four hundred grams might therefore be the load threshold that breaks the cervical postural physiologic balance, whereas the new postural balance is maintained even after the application of an 800-g load per implant. Such a figure suggests that the recruitment of some accessory muscular power might be effective in stabilizing the cervical spine at least up to a load of 800 g per implant.

Although some increase in the lumbar lordosis proportional to the applied breast implant weight was appreciated, such a change proved to be statistically significant only after the use of the 800-g breast implants. All of these changes in the plumbline measurements were quite small and were related to a short experimental time. The actual long-term postural adaptation after breast augmentation with heavy implants is therefore still unknown.

The cervical and lumbar lordoses were demonstrated to vary independently following the application of the same breast implant weights. The small sample size might explain this result.

An increase of the cervical lordosis inversely proportional to the stature, weight, and body mass index of the subjects was demonstrated only after the use of 400-g breast implants. Such a figure might suggest a lesser ability to compensate the implant load in weak-bodied individuals. Similarly, the increase in the cervical lordosis was correlated with a corresponding increase of all related subjective symptoms such as neck pain, dorsal pain, low back pain, or sense of weight without pain after the use of 400-g breast implants only.

Curiously, this correlation was not demonstrated after the use of 800-g implants. Such an apparently conflicting result might suggest the recruitment of supplementary muscle power to counterbalance heavier loads. Nevertheless, these results should be interpreted cautiously, as the associations between $\Delta C7$ values and height, weight, visual analogue scale score, and symptoms did not pass the Bonferroni correction for multiple testing ($p > 0.001$).

The static force platform proved to be a less accurate and less sensitive tool than clinical examination to assess the fine postural alterations after the application of different implant loads. Nevertheless, an increase of the confidence ellipse area in all close parallel feet tests was appreciated after the use of 400-g and 800-g implants, suggesting a worsening of the balance independent from the visual control.

No pathologic alterations of the spinal curves were observed in any case, as the minimum distance measured in our sample from the spinous processes and the plumbline (1.5 cm) always fell within the physiologic range⁸ (Table 1). This result might be explained by the short duration of the implant wearing test, and more severe modifications of the spinal curves might not be excluded in case of prolonged use of breast implants. All of the changes in the cervical and lumbar spine that were demonstrated in our study might be explained by the biomechanical response of the physiologic cervical and lumbar lordosis to a progressive increase of the dorsal kyphosis, because of the implant load, positioned at the same level of the dorsal curve.

CONCLUSIONS

Heavy breast implants proved to induce reversible alterations in the spinal curves, and 400 g is the cutoff for functional physiologic compensation in the short term. Such a weight might be considered the safety limit for the use of breast implants for cosmetic purposes. Further experimental studies are warranted to investigate the effects of the mammary prosthesis load on spine curves in the long term, in a larger sample size, and with the use of a wider breast implant size span.

Our study has obvious limitations, and it would be much more relevant if our findings could be correlated with actual patients to see whether there is adaptation over time. A new prospective study should therefore be carried out on patients undergoing augmentation mammoplasty. Such a trial would be best conceived in a multicentric setting, but we are afraid that it might not be so easy, as, to our knowledge, the cosmetic surgery units performing implantation with very large breast implants are likely to be outside the academic and research environment.

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SUBJECT CONSENT

The subject provided written consent for the use of her image.

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