Physical measurements and patients' perception of excess skin on arms and thighs before and after bariatric surgery

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Received: 28 October 2021 / Accepted: 21 December 2021 / Published online: 13 January 2022
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Abstract

Background Bariatric surgery is an effective weight loss method for patients with obesity. One side effect of bariatric surgery is uncomfortable excess skin. Much remains to be learned about physical measurements and patients' subjective perceptions of it. Here, we investigated the pre- to post-bariatric changes in patients' perception and physical measurements of the skin on the arms and thighs, in order to find possible subgroups especially affected by post-operative excess skin and to identify predicting factors.

Methods One hundred forty-seven patients eligible for bariatric surgery completed the Sahlgrenska Excess Skin Questionnaire (SESQ) and underwent measurements of their skin before and 18 months after the procedure.

Results Although most physical measurements decreased post-operatively, many patients reported increased discomfort. We identified one subgroup particularly prone to report excess skin on the arms post-operatively: women with high discomfort from excess skin on the arms and high body mass index (BMI), pre-operatively. Ptosis of the excess skin seems to be a feasible measurement for predicting post-operative discomfort. For every centimetre of ptosis pre-operatively, patients had 1.37- and 1.31-fold higher odds of achieving a score for post-operative discomfort from excess skin on the upper arms and thighs, respectively, of ≥ 6 (on a 0–10 scale).

Conclusions We identified a subgroup especially affected by discomforting excess skin on arms and thighs after weight loss. Furthermore, we suggest a pre-operative pro-operative ptosis measuring to predict post-operative discomfort level. The result of this study further increases the knowledge of excess skin and should be useful in further improving patient education. Level of Evidence: Level III, risk / prognostic study.

Keywords Excess skin · Body contouring surgery · Bariatric surgery · Reconstructive plastic surgery · Surplus skin

Introduction

Bariatric surgery is an effective method for reducing a patient's body weight and subsequently improving his or her health. Consequently, it has become a common treatment for obesity worldwide [1–4]. As the number of surgeries increases,

however, so does the incidence of adverse effects associated with massive weight loss post-operatively, i.e., excess skin [5–14]; studies have shown that up to 90% of post-bariatric patients experience excess skin [6, 8, 10, 15, 16]. Although most patients are satisfied with their bariatric surgery, some describe the resulting excess skin as “a suit of skin, several sizes too big”; it has been shown to cause significant discomfort, symptoms such as back pain, itching, and rashes, as well as difficulty in finding well-fitting clothes and intimacy issues [6, 10, 13, 15–18]. This may result in a low quality of life (QoL) and/or negative body image, and some patients even regret having undergone the operation [7, 19–24]. Several studies have shown that body-contouring surgery (BCS) is efficient in improving several aspects of QoL for post-bariatric surgery patients with uncomfortable excess skin, including physical functioning, psychological well-being, and social functioning [11, 13, 23, 25–31]. The most common locations for this excess skin are the abdomen, arms, thighs, buttocks, and chest/

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breasts [5, 6, 8, 10, 11, 16, 17, 31–33]. Indeed, the abdomen, upper arms, and chest/breast are the areas for which most subjects have considered BCS [33].

Thus, in most studies, the abdomen is the most common area of the body reported with discomforting excess skin post-bariatric surgery. Staalesen et al. [16], however, showed that among women, excess skin was more commonly reported on the upper arms than on the abdomen, while for men, the upper arms and thighs were the third and fourth most common locations, respectively, for excess skin.

As described above, excess skin causes low self-esteem and QoL, which, for the arms and thighs, can be improved with corrective plastic surgery [34, 35].

Since only a few studies have examined the excess skin on the arms and thighs in post-bariatric patients, knowledge in this field is limited. Thus, the purpose of this study was to investigate, in detail, the amount and development of excess skin on the arms and thighs, both with different objective physical measurements and with subjective reports from the patients, and to evaluate the degree of discomfort that excess skin causes in bariatric patients before and 18 months after surgery. One aim of this study was to investigate whether any subgroup among the patients was especially prone to report discomforting excess skin after bariatric surgery, and another was to investigate the possibility of predicting high post-operative discomfort using the patients' pre-operative physical measurements.

Methods

Patients

Two hundred patients with obesity eligible for bariatric surgery were included in the study between May 2009 and December 2012 at either Sahlgrenska University Hospital or at Carlanderska Hospital in Gothenburg, Sweden. The inclusion criteria were eligibility for bariatric surgery (i.e., body mass index (BMI) $> 35 \text{ kg/m}^2$), and the exclusion criteria were untreated mental illness, ongoing alcohol or drug abuse, ongoing pregnancy, and inability to understand and/or speak Swedish. Patients were provided with verbal and written information regarding the research project and gave their written consent prior to participation. The trial was registered at <https://fou.nu/is/gsb/ansokan/49651>, No: VGFOUGSB-49651, and the local Ethics Committee in Gothenburg, Sweden approved the study (Dnr 723–08).

Of the 200 patients, 149 (109 women and 40 men) participated in the follow-up sessions, and 147 (73.5%) underwent measurements of their arms and thighs.

The patients were measured before and 18 months after their bariatric operations. The measurements followed a standardized protocol, where distances, ptosis, and loose and firm circumferences of the chin, breasts, abdomen, upper arms, inner thighs,

and knees were measured. The protocol was developed, and its reliability was tested by Björserud et al. in 2016 [36, 37]. Measurements of the arms and thighs were used in this study.

The patients also completed the Sahlgrenska Excess Skin Questionnaire (SESQ), in which they assessed any symptoms of excess skin (scores ranging from 1 “never” to 5 “all the time”), the perceived amount of excess skin on different parts of the body (ranging from “none” to “a large amount”), the subjective discomfort of the excess skin (visual analogue scale (VAS) score ranging from 0 “no problems” to 10 “worst possible problems”), and finally any desire for reconstructive surgery [38]. Only questions concerning the arms and thighs were included in this analysis.

Statistics

Means, standard deviations (SDs), medians, minima, and maxima are presented for continuous variables. For comparisons between two groups, the Mann–Whitney *U* test was used for continuous variables. For comparisons over time within groups, the Wilcoxon signed-rank test was used. To evaluate changes over time for categorical and dichotomous variables, the sign test was used.

Pearson's correlation analysis (Tables 3, 4 and 5), Pitman's non-parametric correlation test (Table 5), and Spearman's correlation analysis (Fig. 2C–D) were used to assess the relationship between variables. The resulting correlation was defined as very low ($r_s < 0.25$), low ($r_s = 0.26–0.49$), moderate ($r_s = 0.5–0.69$), high ($r_s = 0.70–0.89$), or very high ($r_s = 0.9–1.00$).

As described above, the patients assessed their discomfort from excess skin on an 11-grade VAS (0–10) in the SESQ. To predict post-operative discomfort, we dichotomized the data into two groups, one with patients with the least discomfort (< 6) and one with the patients with the highest discomfort (≥ 6). For predicting a discomfort level of ≥ 6 18 months after surgery with pre-surgical values, univariable logistic regression was used. The results of the logistic regression are presented as odds ratios (ORs), 95% confidence intervals, *p* values and areas under the receiver operating characteristic (ROC) curve (AUCs).

All significance tests were two-sided and conducted at the 5% significance level.

Results

Demographic data

Table 1 presents the demographic data for the patients who participated in the follow-up session. BMI (kg/m^2) before and 18 months after bariatric surgery did not differ significantly between the two sexes. Regarding the difference in

Table 1 Demographic data and objective measurements of the subjects before and 18 months after bariatric surgery. Δ BMI = difference between BMI before and after bariatric surgery. Values represent themean (SD) and median (min; max). The Mann–Whitney *U*-test was used to evaluate whether the differences between continuous variables were significant

	All N = 149	Women N = 109	Men N = 40	<i>p</i> value between sexes
Age (years)	44.6 (11.5) 44.0 (19;71.0)	43.2 (10.9) 42.0 (19.0;71.0)	48.6 (12.4) 49.5 (23.0;65.0)	0.008
Height (m)	1.70 (0.09) 1.69 (1.48;1.95)	1.66 (0.06) 1.67 (1.48;1.83)	1.81 (0.07) 1.80 (1.68;1.95)	<0.0001
Maximum weight in life (kg)	135.1 (25.1) 130.0 (92.0;237.5)	128.5 (20.5) 127.5 (92.0; 204.0)	153.5 (27.6) 150.0 (123.0;237.5)	<0.0001
Maximum BMI during life (kg/m ²)	46.5 (6.2) 45.2 (34.4;68.8)	46.4 (5.9) 44.8 (34.4;65.9)	47.0 (7.0) 45.7 (36.1;68.8)	0.57
BMI before LRYGB (kg/m ²)	44.4 (5.8) 43.1 (33.7;64.2)	44.6 (5.9) 43.2 (33.7;64.2)	43.7 (5.7) 42.5 (35.1;56.8)	0.31
BMI 18 months after LRYGB (kg/m ²)	30.7 (5.2) 30.1 (20.7;51.9)	30.6 (5.6) 29.7 (20.7;51.9)	31.0 (4.0) 30.6 (23.5;40.2)	0.31
Δ BMI (kg/m ²)	−13.7 (4.2) −13.1 (−24.9; −2.7)	−14.1 (4.1) −14.0 (24.7; −2.7)	−12.7 (4.4) −12.1 (24.9; −3.5)	0.020

BMI before and after bariatric surgery (Δ BMI), however, women lost significantly more weight in relation to their height than men ($p=0.02$).

Upper arms

Objective measurements

The results of the objective measurements for the upper arms are presented in Table 2. The loose circumference decreased significantly for both women and men (−6.80 cm and −6.63 cm, respectively, $p<0.0001$), but the difference between the sexes was not significant. Similar results were obtained for the change in the firm circumference ($p<0.001$).

Pre- and post-operative SESQ-scores

The results of the patients' self-assessments of the degree of excess skin and associated discomfort, reflected in their SESQ scores, are presented in Fig. 1. Post-operatively, women experienced significantly more excess skin and discomfort on the arms ($p<0.0005$) than before bariatric surgery. Men reported significantly more excess skin on the arms after bariatric surgery than before ($p=0.022$) but not significantly more associated discomfort ($p=0.15$).

Correlations

Univariate correlations are presented in Tables 3, 4, and 5.

Regarding the *pre-operative* variables (Table 3), moderate correlations were found between the loose and firm

circumferences of the upper arms and pre-operative BMI. We found no correlations between age and any of the discomfort scores.

Post-operatively (Table 4), there were high to very high correlations between the loose and firm circumferences on the upper arms. Furthermore, there were high correlations between post-operative BMI and both the loose and firm circumferences on the upper arms.

Regarding both the *pre-operative and post-operative variables* (Table 5), moderate to high correlations were found between each pre-operative physical measurement and the corresponding post-operative measurement, and pre-operative and post-operative discomfort was moderately correlated. Finally, there were moderate correlations between pre-operative BMI and the post-operative circumference measurements of the upper arms.

Predicting post-operative discomfort of the upper arms

Independent predictors of high discomfort caused by excess skin on the arms *18 months after* bariatric surgery included discomfort caused by excess skin on the arms *before* bariatric surgery ($p<0.0001$), female sex ($p=0.0099$), and high BMI before bariatric surgery ($p=0.0084$; model $R^2=0.50$). Independent predictors of large ptosis of the skin on the arms *18 months after* bariatric surgery were a large loose circumference ($p<0.0001$) and ptosis ($p<0.0001$) of the skin of the arms *before* bariatric surgery, female sex ($p=0.0016$), and a high maximum BMI throughout the patient's life ($p=0.032$; model $R^2=0.53$).

Table 2 Physical measurements of the skin on the *arms* and thighs before (**B**) and 18 months after (**A**) bariatric surgery and the difference between the two (Δ). LC=loose circumference, FC=firm circumference, P=ptosis. Displayed as the means (SD) and medians (min; max). The Wilcoxon signed-rank test was used to evaluate

whether the differences before and after bariatric surgery (Δ *P* value) within groups were significant, and the Mann–Whitney *U*-test was used to evaluate whether the differences between sexes were significant

		All (<i>N</i> =148)		Women (<i>N</i> =108)		Men (<i>N</i> =40)		<i>P</i> value between sexes
		cm	Δ <i>P</i> value	cm	Δ <i>P</i> value	cm	Δ <i>P</i> value	
Arms								
LC	B	44.3 (5.1)		44.3 (5.4)		44.4 (4.4)		0.49
		43.5 (30; 66)		43.0 (30; 66)		44.0 (34; 57)		
	A	37.6 (5.1)		37.6 (5.5)		37.8 (3.5)		0.45
		37.0 (26; 55)		37.0 (26; 55)		37.0 (30; 45)		
	Δ	− 6.75 (3.95)	<0.0001	− 6.80 (3.91)	<0.0001	− 6.63 (4.11)	<0.0001	0.72
		− 7 (− 21; 3)		− 7 (− 17; 3)		− 6.5 (− 21; 1)		
FC	B	39.8 (4.7)		39.5 (4.8)		40.9 (4.2)		0.028
		39.0 (28; 63)		39.0 (28; 63)		40.0 (32; 53)		
	A	32.2 (4.0)		31.6 (4.2)		33.7 (2.7)		0.0002
		32.0 (23; 48)		31.0 (23; 48)		34.0 (28; 40)		
	Δ	− 7.73 (4.29)	<0.0001	− 7.95 (4.40)	<0.0001	− 7.15 (3.97)	<0.0001	0.21
		− 7 (− 24; 5)		− 8 (− 24; 5)		− 6.75 (− 19; 1.5)		
P	B	4.96 (2.28)		5.36 (2.20)		3.88 (2.17)		0.0003
		5.00 (0; 12)		5.50 (0; 12)		3.75 (0; 9)		
	A	4.95 (2.00)		5.44 (1.85)		3.61 (1.79)		<0.0001
		5.00 (0; 12)		5.00 (2; 12)		3.75 (0; 8)		
	Δ	− 0.05 (2.04)	0.50	0.03 (1.96)	0.69	− 0.26 (2.24)	0.48	0.61
		0 (− 6; 8)		0 (− 3.5; 8)		0 (− 6; 4)		
Thighs								
LC	B	73.2 (8.0)		74.7 (8.0)		69.3 (6.7)		0.0002
		72.0 (47; 99)		75.0 (50; 99)		69.5 (47; 86)		
	A	63.2 (6.7)		63.6 (7.1)		62.1 (5.6)		0.25
		62.0 (50; 88)		62.0 (50; 88)		62.0 (53; 77)		
	Δ	− 10.1 (5.3)	<0.0001	− 11.1 (5.2)	<0.0001	− 7.23 (4.28)	<0.0001	<0.0001
		− 10 (− 25; 6)		− 11 (− 25; 1)		− 8 (− 17; 6)		
FC	B	68.7 (7.4)		69.7 (7.5)		65.8 (6.5)		0.0031
		68.0 (45; 94)		69.5 (47; 94)		65.0 (45; 81)		
	A	58.1 (6.2)		58.0 (6.6)		58.2 (5.0)		0.67
		58.0 (46; 82)		57.0 (46; 82)		59.0 (50; 72)		
	Δ	− 10.6 (5.9)	<0.0001	− 11.8 (5.9)	<0.0001	− 7.59 (4.98)	<0.0001	0.0003
		− 10 (− 33; 5)		− 12 (− 33; 2)		− 8 (− 17; 5)		
P	B	4.06 (2.34)		4.66 (2.18)		2.48 (2.02)		<0.0001
		4 (0; 11)		5 (0; 11)		2.5 (0; 9)		
	A	5.44 (2.03)		6.01 (1.78)		3.88 (1.86)		<.0001
		6 (0; 12)		6 (0; 12)		4 (0; 7.5)		
	Δ	1.35 (2.25)	<0.0001	1.33 (2.27)	<0.0001	1.40 (2.21)	<0.0001	0.99
		1 (− 4.5; 8)		1 (− 4.5; 8)		1 (− 3; 7.5)		

Probability of post-operative discomfort score ≥ 6

The probability of a patient reporting a discomfort score of ≥ 6 (on a scale of 0–10) *after* bariatric surgery in relation to ptosis of the skin *before* bariatric surgery is presented in Fig. 2a. With ptosis of 12 cm *before* surgery, the probability of a discomfort score of ≥ 6 *after* surgery was approximately 80%. Prediction analysis indicated that for every centimetre of ptosis on the upper arms

pre-operatively, there was a 1.37-fold higher odds of the patient scoring ≥ 6 for post-operative discomfort of excess skin on the upper arms on the SESQ (OR = 1.37 (1.14–1.65), $p < 0.0008$, AUC = 0.67).

Figure 2 also shows the relationship between ptosis of the skin and discomfort *after* surgery (c). The data reveal a moderate correlation (0.53) between ptosis on the arms and discomfort after surgery.

Fig. 1 Results from the SESQ.

Percentage of patients who experienced excess skin and their rating of this excess skin in the upper panel and patient rating of their discomfort caused by the excess skin (VAS score, 0–10) in the lower panel. Women in the left column, men in the right column, before (B) and after (A) bariatric surgery. Dots represent means, lines represent medians, and boxes represent quartiles. The Sign test was used to compare the percentage of patients who experienced excess skin, and the Wilcoxon signed-rank test was used to evaluate significance for discomfort

Table 3 Univariable correlation of pre-operative values using Pearson's correlation analysis. Disc=discomfort, UA=upper arms, IT=inner thighs, OT=outer thighs, A=arms, Th=thighs,

LC=loose circumference, FC=firm circumference, P=ptosis. *= $p < 0.05$, **= $p < 0.01$, ***= $p < 0.001$

Variable	Age											
Max BMI	-0.22**	Max BMI										
BMI	-0.19*	0.84***	BMI									
Disc UA	-0.04	0.30**	0.28**	Disc UA								
Disc IT	-0.05	0.22*	0.21*	0.75***	Disc IT							
Disc OT	-0.01	0.27**	0.29**	0.66***	0.60***	Disc OT						
A LC	-0.19*	0.58***	0.60***	0.38***	0.24**	0.23*	A LC					
A FC	-0.22**	0.57***	0.54***	0.28**	0.18	0.08	0.91***	A FC				
A P	-0.08	0.17*	0.26**	0.40***	0.27**	0.25**	0.44***	0.29***	A P			
Th LC	-0.43***	0.44***	0.52***	0.28**	0.16	0.20*	0.52***	0.48***	0.42***	Th LC		
Th FC	-0.46***	0.45***	0.50***	0.25**	0.12	0.14	0.51***	0.53***	0.34***	0.97***	Th FC	
Th P	-0.11	0.08	0.22**	0.24*	0.25**	0.27**	0.11	-0.03	0.44***	0.32***	0.18*	

Thighs

Objective measurements

The results of the measurements of the thighs are presented in Table 2. Both loose and firm circumferences

of the thighs decreased significantly for both sexes (women, - 11.1 cm and - 11.8 cm, respectively ($p < 0.0001$), men, - 7.23 cm and - 7.59 cm, respectively ($p < 0.0001$)). Both measurements decreased more in women ($p < 0.001$). Ptosis of the thighs increased significantly for both women (mean 1.33 cm, $p < 0.0001$)

Table 4 Univariable correlation of post-operative values using Pearson's correlation coefficients. Disc = discomfort, UA = upper arms, IT = inner thighs, OT = outer thighs, A = arms, Th = thighs, LC = loose circumference, FC = firm circumference, P = ptosis. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Variable	BMI	Disc UA	Disc IT	Disc OT	A LC	A FC	A P	Th LC	Th FC	Th P
Disc UA	0.19*									
Disc IT	0.06	0.64***								
Disc OT	0.07	0.46***	0.66***							
A LC	0.82***	0.38***	0.14	0.13						
A FC	0.86***	0.11	-0.08	-0.02	0.89***					
A P	0.43***	0.54***	0.32***	0.22**	0.62***	0.34***				
Th LC	0.78***	0.23**	0.25**	0.25**	0.67***	0.66***	0.46***			
Th FC	0.79***	0.13	0.14	0.16	0.65***	0.71***	0.35***	0.96***		
Th P	0.26**	0.39***	0.48***	0.35***	0.29***	0.07	0.59***	0.55***	0.42***	

Table 5 Univariable correlation of pre- and post-operative values using Pearson's correlation coefficient. The significance test for the correlations was performed with Pitman's non-parametric permutation test. Disc = discomfort, UA = upper arms, IT = inner thighs,

OT = outer thighs, A = arms, Th = thighs, LC = loose circumference, FC = firm circumference, P = ptosis. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

18 months after bariatric surgery											
Before bariatric surgery	Variable	BMI	Disc UA	Disc IT	Disc OT	A LC	A FC	A P	Th LC	Th FC	Th P
	Age	-0.02	-0.20*	-0.38***	-0.18*	0.04	0.05	-0.03	-0.27**	-0.22**	-0.31***
	Max BMI	0.68***	0.34***	0.26**	0.24**	0.62***	0.56***	0.36***	0.56***	0.54***	0.29***
	BMI	0.71***	0.40***	0.27**	0.25**	0.63***	0.52***	0.48***	0.60***	0.55***	0.36***
	Disc UA	0.26**	0.61***	0.44***	0.41***	0.37***	0.16	0.47***	0.24*	0.15	0.37***
	Disc IT	0.13	0.35***	0.46***	0.32**	0.19	-0.01	0.29**	0.12	0.05	0.37***
	Disc OT	0.22*	0.38***	0.38***	0.46***	0.22*	0.1	0.29**	0.23*	0.18	0.28**
	A LC	0.49***	0.41***	0.26**	0.21*	0.70***	0.54***	0.57***	0.49***	0.42***	0.37***
	A FC	0.45***	0.28***	0.14	0.14	0.62***	0.52***	0.43***	0.45***	0.39***	0.31***
	A P	0.23**	0.31***	0.26**	0.23**	0.41***	0.21*	0.56***	0.37***	0.30***	0.41***
	Th LC	0.40***	0.36***	0.37***	0.35***	0.40***	0.30***	0.45***	0.76***	0.64***	0.59***
	Th FC	0.41***	0.32***	0.33***	0.31***	0.38***	0.32***	0.39***	0.74***	0.63***	0.56***
	Th P	0.13	0.29***	0.35***	0.23**	0.19*	0.02	0.43***	0.29***	0.23**	0.48***

and men (mean 1.40 cm, $p < 0.0001$), with no significant difference between sexes.

Pre- and post-operative SESQ scores

The results of the patients' self-assessments of the degree of excess skin and discomfort (SESQ scores) are presented in Fig. 1. Post-operatively, women experienced significantly more excess skin on the inside of the thighs ($p < 0.002$) as well as discomfort from it ($p = 0.0051$) than before bariatric surgery. Men, however, did not report significantly more excess skin on the inner thighs ($p = 0.58$). Neither men nor women experienced more excess skin (or discomfort from such) after bariatric surgery on the outer thighs ($p = 1.00$ and 0.26 , respectively).

Correlations

Univariable correlations regarding the thighs are presented in Tables 3, 4, and 5.

Correlation analysis between pre-operative variables (Table 3) showed moderate correlations between the loose and firm circumferences of the thighs and pre-operative BMI. No correlation was found between age and any of the discomfort scores.

Post-operatively (Table 4), there were high to very high correlations between the loose and firm circumferences on the thighs. Furthermore, high correlations were found between post-operative BMI and both the loose and firm circumferences of the thighs.

Correlation analysis between pre-operative and post-operative variables (Table 5) showed moderate to high correlations between each pre-operative physical

Fig. 2 Top section: probability of discomfort score ≥ 6 (VAS score 0–10) related to excess skin on the arms (A) and thighs (B) 18 months *after* bariatric surgery from ptosis of the skin of the arms and thighs (cm) *before* bariatric surgery with 95% CI (shaded area), using logistic regression. Bottom section: relationship (Spearman's correlation) between ptosis of the arms (C) and thighs (D) in cm and discomfort (VAS 0–10) *after* surgery

measurement and the corresponding post-operative measurement, except for ptosis of the thighs.

Probability of a post-operative discomfort score ≥ 6

The probability of a patient reporting a discomfort score of ≥ 6 (on a scale of 0–10) from excess skin *after* bariatric surgery in relation to ptosis of the skin *before* bariatric surgery is presented in Fig. 2b. With ptosis of 10 cm, the probability of a discomfort score of ≥ 6 was approximately 70%. The prediction analysis indicated that for every centimetre of ptosis on the thighs *before surgery*, there was 1.31-fold higher odds of the patient scoring ≥ 6 points for discomfort of excess skin on the thighs on the SESQ *after surgery* (OR = 1.31 (1.10–1.55), $p < 0.0025$, AUC = 0.65).

Figure 2 also shows the relationship between ptosis of the skin and discomfort *after* surgery (d). The data reveal a low correlation (0.49) between ptosis on the thighs and discomfort ($p < 0.0001$).

Discussion

The aim of this study was to contribute to the knowledge of excess skin on the arms and thighs following massive weight loss. Most clinicians would likely agree that thorough pre-operative information is important to educate the patient and instil in them realistic expectations. However, in accordance with a review by Ellison et al. in 2015 [39], we believe a deeper understanding of excess skin to be important not only for health caregivers and to improve patient education but also to guide the ongoing debate on possible reimbursements for BCS.

We suggest a novel way to predict the level of post-bariatric discomfort from excess skin on the arms and thighs each patient can expect. We chose a cut-off of 6 points on a 0–10 point scale, as a discomfort of 6–10 constitutes approximately the upper half of discomfort scores. As presented in Fig. 2, ptosis of both arms and thighs seems to be a good physical measurement for pre-operatively predicting a post-operative discomfort score of 6 points or more. Furthermore, the linear relationship

between *post-operative* ptosis and *post-operative* discomfort on both arms and thighs also suggests ptosis to be a good physical measurement for objectively evaluating patients experiencing discomfort from excess skin on the extremities.

Post-bariatric reconstructive plastic surgery on the arms and/or thighs due to excess skin is presently not included in, e.g., the Swedish public healthcare system, although the topic is debated. One major question is whether an objective cut-off level for offering surgery can be found, concerning both the ptosis and the degree of discomfort. Our results suggest that objective measurements are a plausible method to identify patients who experience the most discomfort from excess skin and that objective physical measurements may be useful tools for predicting which patients are at high risk of developing excess skin and thus experiencing a high level of discomfort post-operatively. Stepwise multiple linear regression analysis showed that women with high pre-operative BMI who already experienced discomfort from excess skin on the arms constitute an especially affected subgroup. The reason why women are more bothered by excess skin on the arms than men is unknown, but these results match those from previous studies [6, 9, 10, 16, 36, 38, 40]. In the last of these studies, the results showed that women in general report more discomfort from excess skin and report more related symptoms, especially psychosocial symptoms. Women may be more conscious of their appearance, which in turn may be the result of the larger social pressure on this group in terms of beauty ideals. If so, discomfort related to excess skin on the arms does not seem to be an exception. The effect of a high BMI before bariatric surgery on the development of discomforting excess skin has also been reported in previous studies [9, 13, 21]. It is possible that a higher pre-operative BMI causes the skin to become more stretched and subsequently results in more floppy and discomforting skin when the patient loses weight.

One reason to include detailed physical measurements in this study was to evaluate whether ptosis or the loose or firm circumference was affected differently by massive weight loss. The vast decrease in fat volume should cause the skin, muscle, and adipose tissue on the arms and thighs to retract unevenly, possibly causing the ptosis as well as the loose and firm circumference measurements to decrease unevenly. Our results, however, showed that both the loose and firm circumferences of the arms and thighs decreased significantly and fairly evenly. We also found that the ptosis remained unchanged on the arms and actually increased on the thighs. The combination of these changes in physical measurements may cause the skin to become floppier and possibly produce the perception of an increased amount of excess skin. Indeed, the female

patients rated their amount of excess skin on the arms and inner thighs as significantly increased post-operatively, whereas men perceived only their excess skin on the arms to have increased. Furthermore, only women reported more discomfort from excess skin on the arms and inner thighs. This may be because women more frequently wear sleeveless clothes such as tops and dresses as well as shorter pants and skirts.

Whereas the loose circumferences of the arms were approximately the same for both men and women both before and after surgery, women had smaller firm circumferences and larger ptosis both before and after surgery. Regarding the thighs, however, women had significantly larger loose and firm circumferences before but not after surgery, while the ptosis was larger both before and after surgery. The reasons for these differences between the sexes are not clear but may be explained by different muscle and fat distributions in men and women.

Another way we contributed to improved patient information was by mapping correlations between the different pre- and post-operative measurements. We found high to very high correlations between the pre- and post-operative loose- and firm circumferences on both the arms and thighs. This, we believe, indicates that these measurements follow each other and may be interchangeable when used in clinical practice. Furthermore, the analysis revealed moderate to high correlations between each pre-operative physical measurement and the corresponding post-operative measurement (except for skin ptosis of the thighs), suggesting that the skin shrinks proportionately. Finally, the moderate correlations found between maximum BMI during life and the different post-operative circumference measurements postoperatively may suggest that the larger the volume of the body in life, the larger these measurements will remain even after weight loss. The low correlations found between pre-operative BMI and the discomfort scores post-operatively, however, suggest that a high BMI may not necessarily increase the risk of discomfort after surgery. Similarly, post-operative discomfort does not seem to be affected by patient age.

The study has some limitations. Of the 200 patients included in the study, 149 participated in the follow-up, and 147 underwent measurements of the arms and thighs both pre- and post-operatively (73.5%). We found this to be an acceptable participation rate; nevertheless, we do not know why the 53 patients were lost to follow-up, nor do we know how their measurements and questionnaire answers would have contributed to the results of the study. Furthermore, the data used in this study were collected from 2009 through 2012. We used these data because they are extensive and detailed, and we consider them to still be relevant and

reliable. Another limitation is that the SESQ has not been fully evaluated concerning its clinometric characteristics. The reliability has been evaluated and found to be good [38], while validity testing is ongoing.

Conclusions

Although most physical measurements decrease during weight loss, the patients perceive that it increases, and women especially experience discomfort from this condition. Furthermore, it is possible to pre-operatively predict which patients are most at risk of experiencing a high level of post-operative discomfort on the arms and thighs postoperatively. Finally, there are particularly susceptible subgroups among bariatric patients. Together, these new findings should be useful when informing and preparing patients pre-operatively and contribute to the ongoing debate regarding possibly including coverage for BCS of the arms and thighs after bariatric surgery in public or private health care insurance programmes.

Funding Open access funding provided by University of Gothenburg.

Availability of data and material Available on request.

Code availability Not applicable.

Declarations

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee in Gothenburg, Sweden (Dnr: 723–08).

Consent to participate Patients were provided with verbal and written information regarding the research project and gave their written consent prior to participation.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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