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Subcutaneous adipose tissue therapy reduces fat by dual X-ray absorptiometry scan and improves tissue structure by ultrasound in women with lipoedema and Dercum disease

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What is already known about this subject

- Fat tissue manual therapy has been used for centuries to reduce fat in Asian countries.
- The concept that manual therapy can reduce fat tissue is beginning to emerge in the United States.
- Lipoedema and Dercum disease are fat disorders with persistent fat masses that cannot be lost by diet and exercise; therefore, alternative therapies are needed.

What this study adds

- A manual therapy called subcutaneous adipose tissue (SAT) therapy can reduce persistent fat by the gold-standard dual X-ray absorptiometry scan in women with lipoedema or Dercum disease.
- Some fat masses in lipoedema and Dercum disease are associated with blood vessels and can be improved by SAT therapy.
- Manual therapies may serve as an adjunct for reduction of fat tissue.

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Summary

Lipoedema is painful nodular subcutaneous adipose tissue (SAT) on legs and arms of women sparing the trunk. People with Dercum disease (DD) have painful SAT masses. Lipoedema and DD fat resists loss by diet and exercise. Treatments other than surgery are needed. Six women with lipoedema and one with DD underwent twelve 90-min sessions over 4 weeks. Body composition by dual X-ray absorptiometry scan, leg volume, weight, pain, bioimpedance, tissue size by caliper and ultrasound were analysed before and after SAT therapy by paired *t*-tests. There was a significant decrease from baseline to end of treatment in weight, 87.6 ± 21 to 86.1 ± 20.5 kg ($P = 0.03$), leg fat mass 17.8 ± 7.7 to 17.4 ± 7.6 kg ($P = 0.008$), total leg volume 12.9 ± 4 to 12 ± 3.5 L ($P = 0.007$), six of 20 calliper sites and tissue oedema. Pain scores did not change significantly. By ultrasound, six women had 22 hyperechoic masses in leg fat that resolved after treatment; five women developed seven new masses. Fascia improved by ultrasound after treatment. SAT therapy reduced amount and structure of fat in women with lipoedema and Dercum disease; studies are needed to compare SAT therapy to other therapies.

Keywords: Dercum disease, lipoedema, subcutaneous adipose tissue.

Introduction

Women with lipoedema have fat on their hips, buttocks, legs and arms that is persistent despite diet or exercise according to anecdotal evidence in the literature and general agreement among patients and lipoedema practitioners. The ability to lose truncal fat causes asymmetry of the body. A report on two women shows lipoedema fat remaining after bariatric surgery despite a loss of 29–39% bodyweight, and fat loss from other areas of the body (1). There are currently no medical treatments that reduce the persistent lipoedema fat. Many women therefore undergo liposuction to remove the lipoedema fat to reduce pain and improve mobility, appearance and quality of life (2, 3). Inner leg lipoedema fat causes pronation of the feet and genu valgum (knock knees); of 54 women with lipoedema, 25% had knee surgery (4).

The cause of lipoedema is unknown but lipoedema fat becomes heavy with fluid causing fibrosis, spongy or pitting oedema (5) and small and large fatty masses form. Loss of elasticity can occur and skin and fat tissue grow out of proportion folding into lobules; lymphoedema is a serious consequence.

Massaging fat using rolling, pressing and acupressure techniques, historically a treatment to help obese people in China, results in weight loss, and reduction in body mass index, waist and hip circumference (6). A deep tissue therapy that massages fat, muscle and fascia, called SAT therapy, was also shown to reduce leg volume in seven women with lipoedema over 12 sessions, but failed to reduce fat by dual X-ray absorptiometry (DXA) scan (7). In the current study, six of seven women who had undergone SAT therapy (7) returned after four and a half months to undergo 12 additional sessions; one woman with Dercum disease (DD) was new to SAT therapy. Fat amount by DXA, volume by tape measurement, pain by visual analogue scale and ultrasound of fat tissue structure was assessed before and after SAT therapy.

Methods

This study was approved by the University of Arizona Human Subjects Protection Program and all participants consented prior to participation to comply with the World Medical Association Declaration of Helsinki regarding ethical conduct of research involving human subjects. The study design was single arm, non-blinded prospective trial for six women with lipoedema (Table 1 with Critical Etiology Anatomy Pathophysiology criteria (8)) who underwent 12 SAT therapy sessions 4.5 months previous, and one woman with diffuse (very small nodules in fat over the body sparing the head, hands and feet) DD new to SAT therapy. Each session consisted of the same deep manual treatment in areas and time as follows: neck and upper back (10 min), lower back (10 min), upper legs back side (10 min), lower legs back side (10 min), feet (5 min), lower legs front side (10 min), upper legs front side (10 min), abdomen (10 min), arms and chest (10 min) and head and face (5 min) (7). For the current study, all women underwent studies, including physical examination, tape measurements of the neck, smallest and umbilical waist, inframammary, hip, largest and lower arm, leg volume, assessment of heaviness of six locations of tissue (upper arms, hips, buttocks, thighs, breasts, abdomen), strength and flexibility measures (arm curl, chair sit-and-reach and sitting-rising test), bioimpedance (BIA; InBody770, Cerritos, CA, USA), caliper tissue measurements, body temperature, DXA scans, resting energy expenditure (REE) from DXA and indirect calorimetry and tissue moisture by dielectric constant before and after twelve 90-min SAT therapy sessions over 4 weeks (three times weekly) as described previously (7). Participants were asked not to change diet and exercise during the study monitored by questionnaire.

Table 1 Participant baseline demographics

Demographic	Values
Number	7
Age (years)	46.4 ± 5.4
Sex	Female
Race	Caucasian – 5
	Caucasian/Native American – 1
	Native American – 1
Ethnicity	7 Non-Hispanic
Average weight (kg)	87.3 ± 19.2
Average body mass index (kg m^{-2})	32.1 ± 6.9
Average small waist (cm)	84.1 ± 10
Average hips (cm)	117.3 ± 16.2
Average small waist hip ratio	0.7 ± 0.09
Lipoedema stage 1	0
Lipoedema stage 2	5
Lipoedema stage 3	1
Lymphoedema	0
Dercum disease diffuse type	3
Clinical classification scores	C1: 3
for venous disease*	C0: 2
	C2 + C3: 1
	C1 + C3: 1
Number with lipomas	4
Age first symptoms	21 ± 11.4
Number with pain	6

*Part of Clinical Etiology Anatomy Pathophysiology criteria (8).

Arm curl

Subjects lifted a 4 or 5 lb (1.8–2.3 kg) weight in the sitting position flexing at the elbow for as many repetitions as they could in 30 s resting 1 min between tests at the beginning and end study following published methods (9).

Chair sit-and-reach

Hamstring flexibility was tested while participants sat on the edge of a chair and reached over a straightened leg following published methods for left and right legs at baseline and at end of study (10). Reaching the toe line scored 0; reaching beyond the toes scored positive centimetres and reaching short of the toes scored negative centimetres.

Sitting-rising test

Participants sat down from a stand with legs crossed on the floor then stood back up with the least amount of support needed. From a score of 5.0, 1 point was deducted for each use of support (hand, knee, forearm), and 0.5 points for a loss of balance at baseline, and end study following published methods (11).

Ultrasound

Performed on the anterior right leg first, then anterior calf, lateral thigh then calf, posterior thigh then calf, inner thigh then calf, followed by the same areas on the left leg and a low abdomen assessment by one author (DN) using a Phillips IU22 clinical ultrasound machine with an L17-5 transducer (Bothell, WA, USA). Arm volume was measured with the back of the arm against a measuring grid beginning at the wrist and every 4 cm to the upper arm for 12–13 total measurements.

Body shape questionnaire 34

The body shape questionnaire has 34 subjective questions about body shape yielding a possible score between 34 and 204. Proposed classification: less than 80, no concern; 80–110, mild concern; 111–140, moderate concern and greater than 140–204, marked concern with shape (12).

Lower extremity functional scale

Twenty questions about a person's ability to perform everyday tasks, especially related to leg function; best score of 80 (13).

Participant number was limited by time due to a single therapist conducting sessions. The therapist did not participate in data collection or analyses. The participants paid a reduced fee per session. The ClinicalTrials.gov identifier for this study is NCT02907411. Differences between baseline and end study values were by two-tailed paired *t*-tests. Values are ±standard deviation. Pain scores by visual analogue scale were assessed by repeated measures ANOVA; paired *t*-tests compared baseline pain and volume data for six participants to previous end study pain and volume data (7). Alpha of less than 0.05 was considered significant. Data will be available on ClinicalTrials.gov.

Results

Study population

Seven women enrolled in this study, three with lipoedema alone, three with lipoedema and diffuse DD and one with diffuse DD only (Table 1). By questionnaire, subjects reported no change in diet during the time of treatment, and no diuretic use.

Physical examination

Shape

Six women with lipoedema had a gynoid shape; the woman with DD had an android shape.

Oedema

Stemmer sign was negative on hands and feet of all women at baseline and did not change end study. Pitting oedema of the shin area in two subjects at baseline resolved by end study. The number of heavy tissue areas decreased significantly from a baseline average of 3.9 ± 1 to 2.4 ± 1 ($P = 0.003$) at end study.

Fat assessment

Average number of areas with pearl-size SAT nodules out of 22 areas decreased significantly from baseline (5 ± 1) to end study (3.6 ± 1; $P < 0.0001$; Table 2). Fat around the medial malleoli increased for one subject by end study.

Dual X-ray absorptiometry

There was a significant decrease in total body mass from baseline (87.6 ± 21 kg) to end study (86.1 ± 20.5 kg; $P = 0.01$; Table 3). There was no significant difference in total body lean mass (8.4 ± 14.3 kg vs. 8.4 ± 14.4 kg; $P = 0.8$), arm fat mass (4.1 ± 1.3 kg vs. 3.8 ± 0.97 kg) or arm lean mass (4.5 ± 1.1 kg vs. 4.2 ± 1.1 kg) from baseline to end study. Leg fat mass significantly decreased from baseline (17.8 ± 7.7 kg) to end study (17.4 ± 7.6 kg; $P = 0.008$). Leg lean mass did not decrease from baseline (15.8 ± 4.3 kg) to end study (15.1 ± 4 kg; $P = 0.07$).

Resting energy expenditure

There was no significant difference for measured REE between baseline (1357 ± 243.1 kcal day^{-1}) to end study

Table 2 Numbers of participants with nodular fat in different areas of the body before and after subcutaneous adipose tissue therapy

	Number of participants	
Location of nodular fat tissue	Baseline	End study
Cranial	1	0
Wrist cuffs	4	2
Dorsocervical	2	1
Axillary	2	1
Base thumb	3	1
Metacarpophalangeal joint	2	1
Overhanging knee	6	5
Lateral malleoli	7	5
Medial malleoli	3	4
Achilles	4	4
Top of feet	7	5

Table 3 Individual measures of weight, waist and hip before and after subcutaneous adipose tissue therapy

	Baseline			End study		
Subject number	Weight (kg)	Waist (cm)	Hip (cm)	Weight (kg)	Waist (cm)	Hip (cm)
1	113	105	134	111	106	131
2	58	70.5	95	57	70	97
3	98	90	136	95	94	137
4	105	104	129	104	101	130
5	75	90	106	75	90	100
6	85	84	118	85	90	117
7	77	98	104	76	85	102

(1277 ± 214.9 kcal day^{-1}; P = 0.1). Calculated REE from DXA scans did not differ between baseline (1320 ± 173.8 kcal day^{-1}) and end study (1297 ± 159.3 kcal day^{-1}; P = 0.1). There was no significant difference between measured and calculated REE at baseline (P = 0.7) or end study (P = 0.9).

Bioimpedance

Total body water significantly decreased from baseline (35.6 ± 5.4 kg) to end study (34.9 ± 5.4 kg; P = 0.049). Intracellular water (ICW) decreased significantly from baseline (21.9 ± 3.3 kg) to end study (21.6 ± 3.3 kg; P = 0.017). There was no change in extracellular water (ECW; P = 0.14) or ECW/ICW (P = 0.55) from baseline to end study.

Calipers

Six of 20 sites significantly decreased in size from baseline to end study (Table 4).

Body temperature

Forehead temperature significantly decreased from baseline (92 ± 1°F) to end of study (90.5 ± 0.8°F; P = 0.007); otherwise no change in 16 sites on the body.

Pain by visual analogue scale

There was no significant decrease from baseline to end of study in lowest (1.4 ± 2.1 to 1 ± 1.7), average (2.1 ± 2.3 to 1.3 ± 1.9) or highest pain (2.7 ± 2.9 to 1.9 ± 2.3), respectively. Baseline pain scores were not significantly

Table 4 Caliper measurements (mm) at baseline and end of study

Location	Baseline	End Study	% Change	*P* value
Mid lateral neck	8.1 ± 2.8	7.0 ± 2.5	−12.8	0.2
Arm				
Arm, medial to axillae	23 ± 6	15 ± 4.7	−33.9	0.0015
Arm subaxillary	8.3 ± 4.5	6.4 ± 2.7	−23.1	0.1
Biceps	18.8 ± 5	13.7 ± 2.7	−27.3	0.02
Deltoids	38.4 ± 9.3	37.3 ± 7	−2.9	0.5
Triceps	28.5 ± 11	23.7 ± 9	−16.5	0.02
Above elbow	22.4 ± 8.6	18.8 ± 5.4	−16	0.1
Brachioradialis	15.2 ± 6	11.5 ± 2.2	−24.4	0.1
Wrist	8.1 ± 5	5.6 ± 3	−30.5	0.1
Dorsal hand	1.1 ± 0.7	0.9 ± 0.6	−20.5	0.4
Base thumb	3.7 ± 1.8	2.4 ± 0.8	−34.9	0.1
Trunk				
Supra-iliac crest	28.3 ± 12.2	25.9 ± 12.6	−8.6	0.4
Lateral to umbilicus	32.0 ± 11.5	26.5 ± 6.6	−17.3	0.1
Under umbilicus	29.4 ± 13	23.1 ± 13.3	−21.5	<0.04
Subscapular	28.7 ± 9	25.3 ± 8	−11.8	0.1
Low back	40.2 ± 8	35 ± 12.8	−13.4	0.1
Legs				
Anterior thigh	54.0 ± 8.5	48.3 ± 10.2	−10.6	0.01
Inner calf	38 ± 7.2	29.6 ± 5.2	−21.9	<0.008
Dorsal foot	1.2 ± 0.5	1.1 ± 0.3	−11.4	0.4

different from previous end study pain scores (7) for six repeat participants for high pain ($P = 0.35$), average pain ($P = 0.2$) and low pain scores ($P = 0.9$).

Subjective body changes

Five subjects noted less fat in the front and lateral thighs and front and back lower legs, and four noted less inner thigh fat; three or less subjects noted changes in other locations of the body. Five of seven patients stated muscles were more visible, especially on the upper arms. Six of seven patients saw or felt more bones after SAT therapy. Clothes felt looser in six participants after SAT therapy.

Body shape questionnaire 34

Scores did not significantly change from baseline (127.1 ± 32.9 points) to end of study (119 ± 44.7 points; $P = 0.5$).

Lower extremity functional scale

Scores did not significantly change from baseline (72.3 ± 9.7 points) to end study (62 ± 17.5 points; $P = 0.1$).

Ultrasound of fat tissue on the thigh and calf before and after SAT therapy

Masses

Six participants had a total of 22 hyperechoic masses in their calves and/or thighs at baseline that resolved at end of study (Fig. 1). Seven new hyperechoic masses were found in five women end of study (Table 5). The average dimensions of the hyperechoic masses were 1.3 ± 0.85 cm horizontal by 0.8 ± 0.45 cm vertical, with 58.6% surrounding a hypoechoic centre consistent with a blood vessel (Fig. 1). The masses were located directly under the skin, or on average 0.7 ± 0.5 cm below the skin.

Fascia

Fascia planes were better visualized in 12 areas of the thigh of six women and in the calf in one woman (Fig. 2).

Oedema

Four women had a reduction in visual fluid in the tissue (oedema) at the end of study, two women in both calves and one woman each in a single calf.

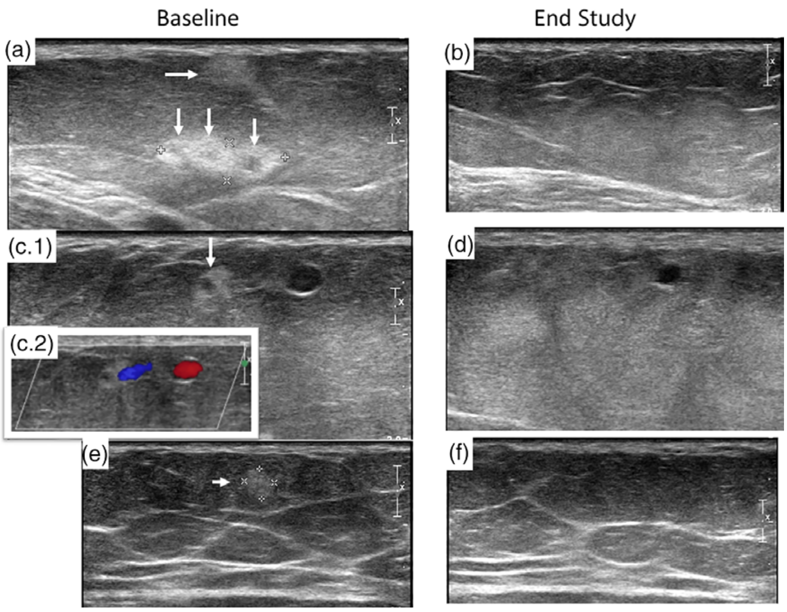

Figure 1 Hyperechoic nodules in three different participants before and after subcutaneous adipose tissue therapy. All ultrasound pictures have skin at the top (white lines). (a) Subject 1: right transverse calf with three hyperechoic nodules (arrows) at baseline. (b) Subject 1: right transverse calf end study shows loss of three nodules. (c.1) Subject 2: nodule just under skin (arrow) and to the left of a vessel (rounded hypoechoic area) at baseline in right anterior thigh. (c.2) Subject 2: colour Doppler flow demonstrates hyperechoic nodule surrounds a vessel (blue) to the left of the larger vessel (red) at baseline in right anterior thigh. (d) Subject 2: nodule to the left of the vessel at end study right anterior thigh no longer be found at end study. (e) Subject 3: single hyperechoic nodule in right anterior thigh (arrow) at baseline. (f) Subject 3: right anterior thigh end study shows loss of nodule. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 5 Number of hyperechoic nodules in fat tissue before and after subcutaneous adipose tissue therapy

	Pre-existing nodules				New nodules	
	Baseline		End study		End study	
Subject number	Thigh	Calf	Thigh	Calf	Thigh	Calf
1	1	2	0	0	2	1
2	2	1	0	0	0	1
3	2	8	0	0	1	0
4	0	1	0	0	0	1
5	2	1	0	0	0	1
6	0	0	0	0	0	0
7	2	0	0	0	0	0
Sum	9	13	0*	0	3	4
Total		22		0		7

*P = 0.012 vs. baseline.

Objective body measurements

Tape measures

There was a significant decrease in size of the inframammary fold from baseline (87.3 ± 7.6 cm) to end of study (85.8 ± 7.5 cm; P = 0.013). There was no significant difference in circumference from baseline to end of study in smallest trunk (84.1 ± 10.1 mm to 83.6 ± 10.3 mm; P = 0.5), umbilical waist (91.83 ± 13.3 cm to 90.9 ± 12.8 cm; P = 0.7; Table 3), hips (117.3 ± 16.2 cm to 110.3 ± 16.6 cm; P = 0.3; Table 3) or pelvic area (106.1 ± 17.5 cm to 102.1 ± 10.7 cm; P = 0.4).

Volume

Average arm volume did not decrease significantly from 2.7 ± 0.7 L at baseline to 2.7 ± 0.5 L at end of study (P = 0.3). There was a significant reduction in total leg volume from 12.9 ± 4 L at baseline 12 ± 3.5 L at end of study (P = 0.007). Baseline volume of the legs for this study was significantly higher than end of previous study for the six repeat women (P < 0.001) but not significantly different from baseline of the previous study (P = 0.2) (7).

Dielectric constant

There was no significant difference in dielectric constant of the hands from baseline (39.93 ± 5.2) to end of study

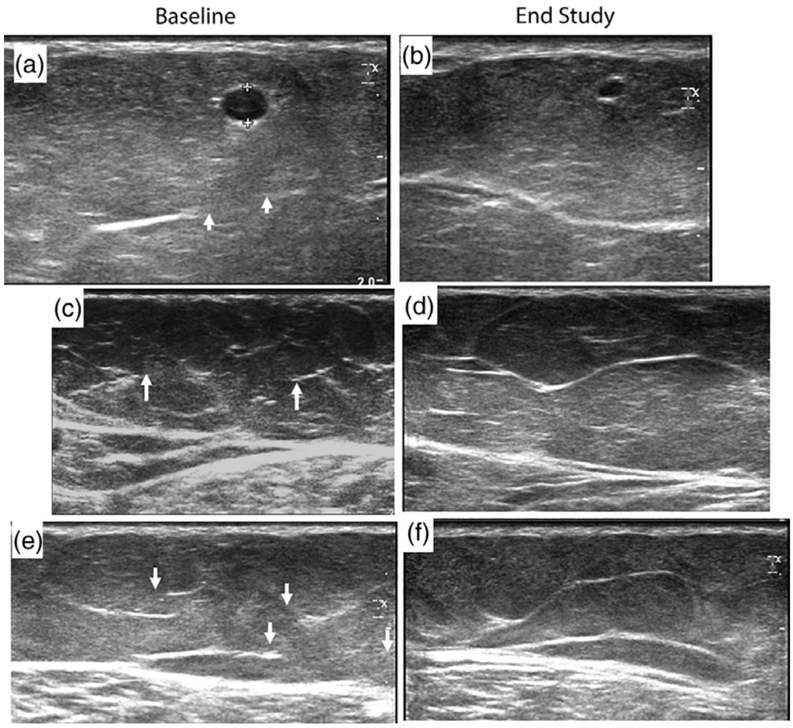

Figure 2 Loss of visualized fascia lines in three different participants before and after adipose tissue therapy. Subject 1: (a) Loss of visualization of fascia in the right posterior thigh before adipose tissue therapy (between arrows). (b) Visualization of fascia end study. Subject 7: (c) Visualized fascia appears fragmented in the right inner thigh before adipose tissue therapy. (d) Resumption of a more linear fascia line after therapy. Subject 2. (e) Irregular fascia in the left lateral calf before adipose tissue therapy (between arrows). (f) Resumption of linear lines around fat lobules after adipose tissue therapy.

(42.9 ± 5; P = 0.2) or feet from baseline (39.8 ± 3.2) to end of study (38.1 ± 6; P = 0.5).

Functional assessment

There were trends towards improvement in the stand-sit-stand score from baseline (3.6 ± 1.4) to end of study (4.2 ± 1.2; P = 0.07) and in right arm curl from baseline (20.6 ± 6.6 reps) to end study (23 ± 5.2 reps; P = 0.06). There was no change in chair sit and reach scoring on the right from baseline (7.7 ± 9) to end of study (10.3 ± 4.2; P = 0.2) or left from baseline (10.7 ± 5.3) to end of study (10.4 ± 4.6; P = 0.9).

Signs and symptoms during subcutaneous adipose tissue therapy

During SAT therapy, one person developed diarrhoea. All seven subjects stated the therapist treated deeper into the tissue from the first to last session.

Sensitivity

Sensitive areas during SAT therapy were front lower legs (n = 2), upper abdomen (n = 2), around the knee (n = 3), behind the knee (n = 1) and under the knee (n = 1).

Bruising

Five women experienced bruising in the upper arms (n = 4) and in the front of the thighs (n = 3) during SAT therapy.

Swelling

As the therapist treated deeper into the tissue, the number of women who had swelling increased: first through seventh sessions (n = 1); eighth through ninth sessions (n = 2); 10th through 11th sessions (n = 3); and 12th session (n = 5).

Pain

Five women experienced pain or tenderness in their fat before SAT therapy which reduced in four; one woman continued to feel pain.

Discussion

Persistent fat that resists loss from diet, exercise or bariatric surgery despite other fat reducing on the body is a newer concept in obesity and is present in people with lipoedema and DD. As there is no drug or lifestyle change that effectively reduces persistent fat, many people with lipoedema and DD undergo liposuction or surgical excision to remove painful fat and improve mobility and quality of life. This study found that deep SAT therapy reduced persistent fat on the legs of women with lipoedema by the gold-standard DXA scan, 0.4 kg or approximately a pound of fat.

Obese fat becomes fibrotic (14) restricting blood flow in and lymph flow out (15). These changes in fat contribute to resistance of persistent fat to weight loss (14). The asymmetric location and the presence of persistent fat make lipoedema fat, however, different from lifestyle-induced obesity; the pathophysiological difference between obese and lipoedema fat remains unclear. SAT therapy is likely effective in reducing persistent fat by changing its structure and improving its function. As proof, cellulite massage therapy improved the smoothness of the skin in women (16). While we did not examine smoothness of skin, we found a reduction in skin caliper size of the skin; in addition, we found a reduction of fibrosis and hyperechoic nodules in the fat tissue. SAT therapy may also return fat metabolism towards normal as shown for a mechanical massage in nine healthy females that improved the lipolytic responsiveness of femoral fat tissue following perfusion of a lipolytic agent; this however remains to be tested (17). Changes in fat structure may improve blood and lymph flow, which may make persistent fat more amenable to change.

Fat massage is not new. Meridian massage, technically a fat and deep tissue massage, has been performed for centuries by Chinese practitioners (6). Massage has also been performed to improve circulation and vascular function (18), reduce weight in DD (also known as adiposis dolorosa) (19) and, more recently, reduce fat in preterm infants (20). Since SAT therapy reduced an average of 0.4 kg of lipoedema fat, SAT therapy and other deep tissue fat therapies may therefore be beneficial as adjuncts to weight loss therapies.

A major finding in this study was the finding of ~1 cm hyperechoic masses in lipoedema and DD fat tissue that were associated with blood vessels. The nodules were directly under the skin or within a centimeter of the skin and are therefore consistent with the palpable masses felt on examination. These masses may signify a leaking vessel, a bruise or inflammation surrounding a vessel; easy bruising is one of the common signs of lipoedema. SAT therapy effectively reduced 22 hyperechoic nodules, thereby improving the area around blood vessels or the blood vessels themselves. Seven new hyperechoic nodules appeared at end study suggesting that lipoedema pathology did not completely resolve.

One of the most consistent findings in lipoedema fat is the loss of distinction of areas of fascia in the fat tissue by ultrasound; however, these findings were difficult to demonstrate on still pictures (Fig. 2). The lack of distinctness of the fascia bands improved over the course of the study similar to published data showing laser therapy improves fascia structure in fat tissue (21). As lipoedema tissue holds on to fluid by definition, it is likely that oedema in the fat tissue blurred and/or shifted fascia lines; reduced body water after SAT therapy as confirmed by BIA in this study may have reduced blurring of the fascia lines seen by ultrasound. Temporary tattoos would be helpful in confirming pathology in areas assessed by ultrasound in future studies.

Pain levels were not significantly reduced by the SAT therapy in this study. However, six of the participants had previous SAT therapy (7) and their pain reduced over the course of that therapy and remained reduced during this second study. Volume did not remain reduced in the women after the first study; fluid may have been present in the tissue of the women because the majority travelled to the location of the study. That fat did not significantly reduce by DXA scan in the first study suggests more than 12 treatments of SAT therapy are needed to reduce fat tissue.

While there was no change in flexibility after SAT therapy, strength tended to increase. Additional participants (more than seven) are needed to better assess if SAT therapy affects strength.

This study was limited by the low number of subjects, lack of comparison to other therapies and lack of control for other lifestyle factors as part of this study. Additional studies are needed to compare SAT therapy to other therapies such as manual lymphatic drainage therapy, and the structure of the tissue needs to be assessed by other measures, including biopsies of skin and fat tissues, and assessment of blood flow in and lymph flow out of the fat (15). One strength of this study is that all subjects were treated by the same therapist.

Conclusion

Treatment of fat tissue with a manual SAT therapy improved the structure, reduced masses and nodules and reduced the amount of tissue fluid in lipoedema and DD. These data suggest that improving the structure of fat tissue may allow for weight loss in fat disorders. SAT therapy needs to be tested for benefits against other manual therapies.

Conflict of Interest

AE owns Quadrivas Clinic & Academy in the Netherlands where she instructs practitioners in SAT therapy, called Quadrivas Therapy. The other authors state no conflict of interest.

Author contributions

KLH and AE conceived the experiments. KLH, CU, DN and KG carried out experiments. and AE performed all treatments. MI and KLH analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published versions.

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