

Research Article

Surgical Reduction of Visceral versus Subcutaneous Fat and Effect on Features of the Metabolic Syndrome

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Abstract

Background

Obesity results in both health and financial tolls for individuals and society. Despite the great efforts to increase awareness, the obesity epidemic continues at an alarming rate. Subcutaneous fat represents 85% of the fat mass in obese patients, while intra-abdominal fat, including both visceral and retroperitoneal adipose, represent about 15%. Both subcutaneous and visceral fat have a negative effect on individual health and promote metabolic diseases. Logic would thus suggest that adipose tissue removal by liposuction and/or visceral tissue removal could effect an improvement in metabolic diseases such as Type 2 diabetes?

Methods

The scientific literature was searched to illustrate and describe the effect of adipose tissue on metabolism and the effect of its removal on inflammatory and metabolic markers.

Results

Adipose tissue is an endocrine organ and in obesity serves as a source of systemic proinflammatory signals arising from stressed adipocytes and/or infiltrating macrophages. These signals are associated with insulin resistance, dyslipidemia and hypertension (metabolic syndrome). The benefits of fat removal on metabolic syndrome remain controversial.

Conclusion

Visceral and subcutaneous fat is associated with high risk of coronary heart disease, insulin resistance, and other metabolic risk factors. Abdominal lipectomy is a well-known cosmetic procedure and used widely for its benefits on improving body image. However, its benefit on the metabolic disorder remains inconclusive. On the other hand, current evidence would suggest that omentectomy offers no benefit in relation to improvements in systemic inflammation and metabolic control. Removal of visceral adipose tissue in and of itself would thus appear to have limited efficacy as an approach to the treatment of the obesity-related metabolic syndrome.

Key words: Visceral and subcutaneous fat, Liposuction, Omentectomy, Metabolic Syndrome

Introduction

Obesity is defined as a systemic disease that shows excessive and abnormal accumulation of body fat leading to adverse health effects. Obesity has negative effects on health and exerts significant financial tolls on individuals and society. Despite significant efforts to increase awareness, the obesity epidemic continues at an alarming rate [1]. More than 50% of the European population is overweight and up to 30% is obese with prevalence worldwide doubling since 1980 [World Health Organization 2011] [2].

Abdominal obesity is defined as increased visceral fat and trunk subcutaneous fat which leads to increased waist circumference [3].

The contribution of abdominal subcutaneous fat mass and the visceral fat mass to the pathogenesis of metabolic disease is controversial, but it is associated with high risk of coronary heart disease, insulin resistance, and other metabolic risk factors[3, 4].

Subcutaneous fat represents 85% of the fat mass in obese patients, while intra-abdominal fat, including both visceral and retroperitoneal adipose, represent about 15%[5]. Visceral obesity is presumed to predispose individuals to hepatic insulin resistance based on its anatomical site and venous drainage to the liver through the passage of adipocytes products into the portal vein[6-8].

Waist circumference [WC] and waist to hip circumference ratio [WHR] are used to measure abdominal obesity [9, 10], Body mass index [BMI] which equals the ratio of weight in kilograms divided by height in meters squared [kg/m²] is used to measure general obesity [11]. Each of these three parameters can be used to measure the association of obesity and metabolic risk factors, but the combination of the three [BMI, WC, and WHC] appears more useful than the use of BMI alone [12, 13].

Theoretically, WC cut-off results are >88 cm in women and >102 cm in men but actually, it is difficult to apply in all populations due to the marked difference in the average levels of measurement. Asians are characterized by higher morbidity at lower cut-off for WC than other populations [14].

The metabolic effects of visceral and subcutaneous adipose tissue

Although body fat mass distribution is characterized by marked individual variations it can generally be classified into the following four types, a) Abdominal subcutaneous: most of the fat stored subcutaneously around the stomach and chest, b) Lower body: fat storage around the thighs, hip, and buttocks, c) Overall coverage: fat accumulation in the arms, breast, thighs, buttocks, lower back and breast, d) Visceral: fat deposition within visceral cavity surrounding the viscera including stomach, intestine, liver and pancreas [Figure 1] [15].

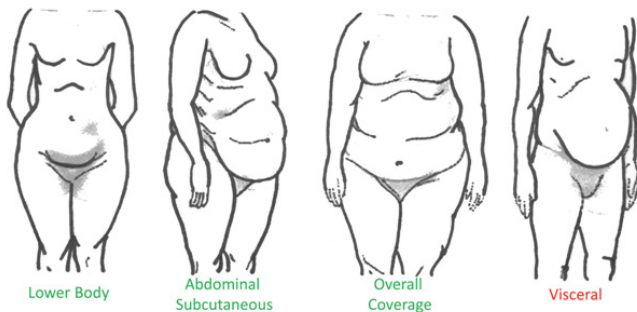


Figure 1. Types of body fat mass distribution[15]

More specifically, upper body fat distribution and increased visceral fat is more associated with metabolic dysregulation[16-18] than lower body and abdominal subcutaneous fat accumulation [19, 20]. Metabolic disorders associated with subcutaneous and visceral obesity include insulin resistance, type 2 diabetes [21, 22], dyslipidemia [23], and hypertension [24, 25].

Adipose tissue is an endocrine organ producing proinflammatory molecules from adipocytes and/or infiltrating macrophages in patients with high BMI, WC, and WHC [26]. These include tumor necrosis factor- α [TNF- α], C-reactive protein [CRP], interleukin-18 [IL-18], and interleukin-6 [IL-6] [27-30]. These cytokines have been linked to impairments in insulin action in liver, muscle, and adipose tissue [31-33].

TNF- α in obesity is increased in both systemic and portal circulation [32], which affects insulin sensitivity within adipocytes and stimulates secretion of IL-6 [34] Also, IL-6 concentration is 50%

higher in the portal vein than in the peripheral circulation for patients with high visceral obesity [32].

Leptin and adiponectin expression is higher in subcutaneous fat compared with visceral adipose tissue [35, 36], but cytokine expression such as IL-6, IL-8 appears to be higher in visceral adipose tissue compared with subcutaneous fat [37].

Excess visceral and subcutaneous fat mass are associated with an elevation in postprandial [38] and post-absorptive fatty acid concentration in portal vein and systemic circulations [39]. Chronic exposure of the liver to the high concentration of free fatty acids promotes liver gluconeogenesis facilitating hepatic glucose production, thus providing a continuous source of energy and substrate that tends to raise fasting glycaemia [8, 40]. Increased insulin resistance and reduced fatty acid oxidation increase fat storage and synthesis in the liver [41-43].

Adipose tissue removal surgeries

Liposuction

Liposuction is one of the most common plastic surgeries and aims to remove subcutaneous adipose tissue from different body areas so as to improve body image and create more physical balance [44]. Since its introduction by Illouz 30 years ago, its popularity has rapidly increased, making it the second most common cosmetic surgical procedure in 2012 [313,011 patients] [45]. nearly 400,000 procedures are performed annually in USA [45].

The removal of subcutaneous fat with a blunt cannula attached to a suction generating device was first popularized in Europe in the late 1970s. The procedure of liposuction has undergone many refinements and evolved with improvement in techniques and technology since its introduction by Illouz in 1982 [46-48].

a) Traditional liposuction

Liposuction was first practiced without any preparation of the fat before suctioning it from the subcutaneous tissue and this was called 'Dry liposuction' which was associated with a high incidence of hemorrhage and hematoma. Then Illouz developed the wet technique by injecting normal saline, water, and hyaluronidase to create a weak hypotonic solution to destroy the fat cell wall [49]. Hetter added lidocaine and dilute epinephrine to the injected solution [50], then the super wet and tumescent techniques were developed by injecting the standard wetting solution [1 ml of epinephrine and 50ml of 1% xylocaine for each 1 liter of lactated Ringer solution] [51].

The ratio of the volume of wetting solution infused to the volume of fat aspirate is 1:1 in wet technique but 2 or 3:1 in the tumescent. Although, wetting and tumescent techniques are different in this ratio, they both involve infusion of the wetting solution to the point of tissue turgor or a "peau d'orange" of the overlying skin followed by suction of the subcutaneous tissue [51].

b) Ultrasound-assisted liposuction[UAL]

Zocchi is credited for the application of ultrasonic energy in liposuction to allow more selective tissue targeting [52]. It works by having expansion and compression parts of the cycle as a sound

wave, which exerting a negative pressure that overcomes molecular forces results in cellular fragmentation with the intracellular content release, which leading to interstitial cavities hence termed as cavitation. Subsequently, a low-power suction can be performed [52, 53]. In this technique, sufficient amount of wetting solution must be used to limit the effect of heat generated by Us probe. Cellular disruption has been confirmed by the homogenous, macroscopically-acellular aspirated fat which contains a high level of adipocyte-specific intracellular glycerol 3-phosphate dehydrogenase isozyme [54]. UAL is highly efficient in removal of fat in fibrous areas such as the upper back, the hypogastrium, and the breast. UAL has been shown to cause less disruption of vasculature than SAL and hence less bruising [55].

c) Power assisted liposuction [PAL]

In the late 1990s, PAL was developed to subside some of UAL side effects. Actually, it is traditional liposuction with a special reciprocating cannula [Figure 2]. It is useful for fibrous rich areas liposuction and easy for the surgeon to use. No heat generation considers its main advantage over PAL [56].

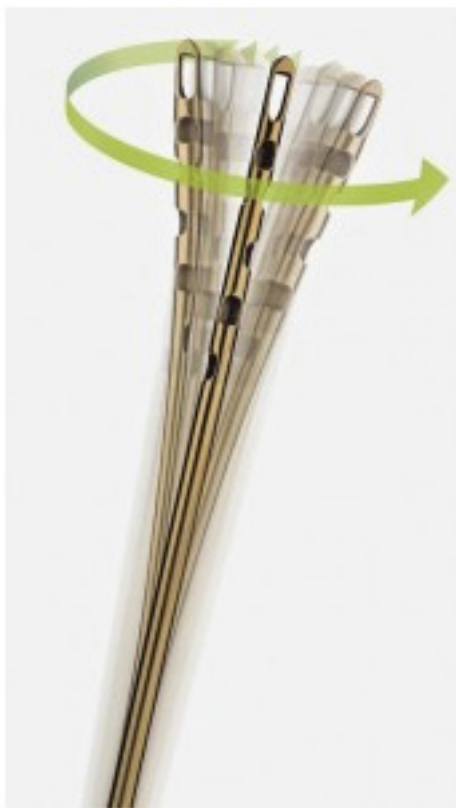


Figure 2. Power assisted liposuction cannula

d) Laser-assisted liposuction [LAL]

LAL is defined as, the simultaneous use of a bare laser fiber as a free beam or a confined beam to lyse, liquefy the fat while simultaneously coagulating small blood vessels at the cannula fat interface. Harness in 1990 described the use of 1064 nm Nd-YAG laser for liposuction with promising results such as minimal incision and skin contraction produced by its photothermal effect [47]. Recently, the use of 1,320-, 1,440- and 2,100-nm wavelengths also have been proposed, with claims

of less bleeding, faster healing, and better tissue tightening using laser lipolysis [57-60].

e) Radiofrequency-assisted liposuction [RFAL]

Radiofrequency-assisted liposuction [RFAL] means usage of bipolar radiofrequency energy [similar to that of diathermy] to disrupt the fat cell membrane and facilitate lipolysis with a lesser requirement for suction power [61, 62]. A controlled subdermal thermal injury produced by this energy leads to healing by contraction which produces a secondary effect on skin contraction such as LAL [61]

Omentectomy

Omentectomy [OM] defined as, surgical removal of the whole greater omentum which is a thin fold of abdominal tissue that encases the stomach, large intestine, and other abdominal organs. There are two main types of omentectomy: completely removing the omentum which is called total or supra colic omentectomy and removing a portion of the omentum which refers to partial omentectomy.

The procedure may be performed traditionally or laparoscopically, the traditional approach involves mini-laparotomy with a median supraumbilical incision of 8 to 10 cm to release the omentum from the large gastric curvature while preserving the gastroepiploic artery [63].

Laparoscopic omentectomy technique: Four trocars are used to reach the abdominal cavity at the following positions, under the umbilicus, right lower quadrant, and two at left lower quadrant [63]. After inflation of the abdominal cavity, body and fundus of the stomach are released from the greater omentum and short gastric vessels by harmonic scalpel with remaining of gastroepiploic vessels intact. After detaching the omentum from the transverse colon pulled out through the infra-umbilical incision [64].

Effect of adipose tissue removal on metabolic disease

Liposuction

A study by Giugliano et al, examined the effect of subcutaneous fat suction on insulin resistance and vascular inflammatory markers in 30 obese women by comparing the pre and postoperative [6 months] HOMA [fasting plasma glucose [mmol/l] x fasting serum insulin [mU/ml] divided by 25] as an index of peripheral insulin resistance., High HOMA scores denote low insulin sensitivity. Levels of IL-6, IL-8, TNF- α , CRP and adiponectin were also assessed. Results demonstrated that liposuction was associated with significant decrease in all parameters, except adiponectin, which significantly increased [Table 1] [65]. The risk of cardiovascular death and the incidence of insulin resistance was reduced at follow-up in association with improvements in metabolic and inflammatory markers.

In a study by Ramos et al, patients underwent abdominoplasty from October 2010 to September 2011. Total cholesterol, high-density lipoprotein [HDL], low-density lipoprotein [LDL], very low-density lipoprotein [VLDL], triglycerides, glucose, insulin, and HOMA index were measured preoperatively and 3 months post-operative. The results showed a significant reduction in triglyceride and LDL and a non-significant trend for improvements in HOMA, cholesterol, glucose, insulin and HDL [Table 2] [66]. The findings of this study were more

or less similar to the Swanson study, which included 322 patients and demonstrated a significant reduction in triglycerides only [67].

Table 1. Results of Giugliano et al, study[65].

| | | Baseline | Six months postoperative | P-value |
|-------------|-------|----------|--------------------------|---------|
| Weight | | 88 | 85 | <0.001 |
| HOMA | | 4.1 | 3.08 | <0.05 |
| IL-6 | pg/ml | 4.1 | 3.2 | <0.05 |
| IL-18 | pg/ml | 246 | 219 | <0.05 |
| TNF-a | pg/ml | 5.1 | 4.1 | <0.02 |
| CRP | ml/l | 2.9 | 2.4 | <0.02 |
| Adiponectin | ug/ml | 5.1 | 6.4 | <0.02 |

Table 2. Results of Ramos et al., study [66].

| | | Baseline | Three months postoperative | P-value |
|--------------|-------|----------|----------------------------|---------|
| Weight | kg | 69.1 | 68.6 | 0.79 |
| Glucose | mg/dl | 91.45 | 90.71 | 0.81 |
| Insulin | U/ml | 17.11 | 11.79 | 0.28 |
| HOMA | | 3.96 | 2.58 | 0.22 |
| Cholesterol | mg/dl | 224 | 220 | 0.84 |
| Triglyceride | mg/dl | 193 | 133 | 0.03 |
| HDL | mg/dl | 44 | 49 | 0.18 |
| VLDL | mg/dl | 43 | 39.1 | 0.55 |
| LDL | mg/dl | 137 | 79.61 | 0.04 |

In the cohort study of Marfella et al, 20 patients underwent abdominoplasty and 28 patients were exposed to diet, exercise, and behavioral counseling. Authors compared preoperative and 2-month postoperative measurements of triglycerides, insulin, insulin sensitivity, IL-6, TNF- α , and HDL-cholesterol. A significant reduction in triglycerides and insulin and improved insulin sensitivity was observed in both groups, with significant decreases in IL-6 and TNF- α occurring only in abdominoplasty group. There were no changes in HDL-cholesterol during the study period [68]. In a prospective cohort study, 12 obese patients that underwent abdominoplasty were followed up and plasma triglycerides, HDL, cholesterol, and insulin sensitivity measured during the preoperative period and at 50 days postoperative [69]. In difference to other studies in the field, no improvements were observed in any of the parameters studied.

An overall survey of the literature suggests that on balance, besides the cosmetic results of liposuction, a positive impact on lipid profile and other metabolic markers can arise as a secondary benefit of the procedure. However diet, lifestyle, and exercise modification subsequent to liposuction are likely to significantly enhance the magnitude and duration of beneficial effects by preventing new fat deposition [66]. Whether liposuction can be advocated primarily for its metabolic effects remains however rather controversial and there is still an insufficient evidence base to support its use in this context.

Omentectomy

Fabbrini et al, conducted a randomized controlled trial to test the hypothesis of the effect of visceral fat removal on metabolic diseases.

Eleven patients underwent laparoscopic combined Roux-en-y [RYGB] with omentectomy, but RYGB alone was performed to the same number. Leptin, blood glucose, HbA1c, insulin, CRP, cholesterol, LDL, HDL, and triglyceride were measured preoperatively, 6 months and 12 months postoperative. Results of comparing pre and postoperative investigations demonstrated that hepatic insulin sensitivity increased 4-fold and skeletal muscle insulin sensitivity approximately doubled at 12 months after surgery in both groups, Critically no significant augmentation of improvements in these parameters was observed in patients undergoing omentectomy. So, metabolic variables improved after RYGB surgery but visceral fat removal has no additive effect on these variables . [70]. However, these data did not preclude the possibility that stand-alone omentectomy could be of metabolic benefit. To examine this, the same trial incorporated a treatment arm in which 10 patients underwent laparoscopic omentectomy alone. Results demonstrated that metabolic variables and minimal model-derived indices of insulin sensitivity, glucose effectiveness, and Beta-cell function did not change significantly 3 months after omentectomy compared with baseline [70].

Lima et al, and Herrera et al, are two prospective randomized trials looking at omentectomy[71, 72]. Both studies randomized patients equally into two groups, patients of the first group underwent RYGB with omentectomy but RYGB alone was performed to patients of the other group. Both studies used blood samples to measure metabolic and inflammatory markers for patients as in the study of Fabbrini and drew the same conclusions, i.e. omentectomy did not confer any additional benefit on top of RYGB.

From the previous studies and trials, it is thus clear that omentectomy does not induce any improvement in the components of metabolic syndrome and inflammatory mediators. Given the constitutive protective function of the omentum in the abdomen, there appears to be no basis for pursuing omentectomy as a viable intervention for metabolic disease.

Conclusion

Theoretically, increased visceral and subcutaneous adiposity are major risk factors for insulin resistance, dyslipidemia, and other metabolic disorders. Abdominal lipectomy is a well-known cosmetic procedure and used widely for its benefits on improving body image. However, its benefit on the metabolic disorder remains controversial. On the other hand, Omentectomy also does not induce any improvement in the components of inflammatory mediators but its effect on metabolic diseases considered an arguable issue. The currently available literature on visceral fat removal and liposuction are characterized by a small number of patients, we need more powerful randomly controlled trials to provide additional evidence. Intriguingly the fact that removal of subcutaneous rather than visceral fat, [at least the omentum] confers metabolic benefits, challenges current orthodoxy regarding the involvement of the two major fat depots in metabolic syndrome.

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