REVIEW ARTICLE

How does adipose tissue fat content change after a weight loss intervention?

Takashi Abe, Robert S. Thiebaud, Jeremy P. Loenneke

Fat-free mass (FFM) estimated by dual-energy X-ray absorptiometry (DXA) and densitometric methods (e.g. underwater weighing or air-displacement plethysmography) contains the fat-free component of adipose tissue. Weight loss reduces triglycerides in adipocytes and this automatically reduces the fat-free component of adipose tissue (assuming the fat fraction percentage is maintained after weight loss). The loss of this fat-free component reflects a reduction in whole body FFM. However, the reduction of the fat-free component of adipose tissue does not mean a change in actual FFM i.e., muscles and organs. Regrettably, little attention has been paid to adipose tissue fat content changes following weight loss.

Objective: To discuss the change in fat fraction percentage of adipose tissue following weight loss interventions.

Design: Narrative Review.

Methods: Databases and a search engine were used to search for relevant articles.

Results: There are three possible processes for determining adipose tissue fat content: (i) measure the components of adipose tissue using biopsy samples; (ii) measure the fat mass by DXA and the adipose tissue volume by magnetic resonance imaging and find the ratio of fat mass to adipose tissue volume; and (iii) measure the chemical shift-based water-fat by magnetic resonance imaging.

Conclusion: Very few studies were found that reported changes in adipose tissue fat content with weight loss. We reported changes in adipose tissue fat content using three different processes but a consistent trend was not found. As a result, we were unable to conclude how much adipose tissue fat content changes after weight loss.

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Key words: Adipose tissue ■ Fat content ■ Fat-free mass ■ Weight reduction

INTRODUCTION

There are several methods currently used to reduce body weight. These methods include exercise, calorie restriction and bariatric surgery which create a negative energy balance that leads to weight loss. This weight loss primarily means a reduction in body fat, but often a loss of fat-free body mass (FFM) is also observed.[1] Adipose tissue is mainly composed of closely packed adipocytes (fat cells) combined with collagen and elastic fibers, and the adipocytes store a high proportion of triglycerides. However, the contents of adipose tissue do not only contain triglycerides, but they also include fat-free components (i.e. water and protein). The FFM estimated by dual-energy X-ray absorptiometry (DXA) and densitometric method (e.g. underwater weighing or air-displacement plethysmography) includes the fat-free component contained in adipose tissue. Moreover, weight loss does not only reduce triglycerides in adipocytes, but the fat-free component of adipose tissue also automatically changes, reflecting a reduction in whole-body FFM.[2] Minimizing the loss of FFM is usually considered important because decreasing FFM is a factor that can reduce resting energy expenditure and produce weight regain.[3] A previous study suggested that 85% of adipose tissue is triglycerides (fat) and 15% of adipose tissue is the remaining calculated fat-free component.[4] When using the proposed model,[4] it is predicted that a loss of 10 kg body fat will simultaneously reduce approximately 1.8 kg of the fat-free component of adipose tissue. It should be noted that the reduction of this component does not mean a change in the actual FFM i.e., muscles and organs. However, attention has not been paid to adipose tissue fat content changes following weight loss. If the adipose tissue fat content changes during the process of weight loss, the contribution of the adipose tissue component to the change in FFM becomes altered.[5] Therefore, we will discuss the possibility of determining the change in fat fraction percentage of adipose tissue following weight loss interventions.

METHODS AND FINDINGS

Currently, there are three possible processes for determining adipose tissue fat content: (i) Measure the components of adipose tissue using biopsy samples, (ii) Measure the fat mass by DXA and the adipose tissue volume by magnetic resonance imaging (MRI) and find the ratio of fat mass to adipose tissue volume, and (iii) Measure the chemical shift-based

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From the Department of Health, Exercise Science, and Recreation Management, Kevser Ermin Applied Physiology Laboratory, The University of Mississippi, Oxford, MS, USA (T.A., J.P.L) and Department of Human Performance and Recreation, Brigham Young University – Idaho, Rexburg, ID, USA (R.S.T.)

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Correspondence to: Dr. Takashi Abe, 218C Turner Center, University, MS 38677, USA
Email: t12abe@gmail.com

water-fat by MRI. Of note, it is important to ensure that the variables are in the same units when measuring fat mass by DXA and adipose tissue volume by MRI. This can be done by converting volume to mass units (by multiplying the volume by a constant). In contrast, chemical shift-based water-fat MRI calculates the quantitative ratio of signals (volume) from lipids and water in tissues.

The fat component of adipose tissue biopsy samples

One study[6] reported the changes in body composition and subcutaneous adipose tissue components following weight reduction in two human subjects. After calorie restriction, body mass decreased by 8.4 kg (-9.4% of body mass) for subject E and 14.9 kg (-14.7% of body mass) for subject B. As a result, the adipose tissue fat content decreased from 85.7% to 78.0% (Δ -7.7%) in subject E, and from 79.2% to 62.3% (Δ -16.9%) in subject B (Table 1). This study investigating the component analysis of adipose tissue suggested a decrease in adipose tissue fat fraction percentage with weight loss, but the number of subjects was small and no other reports were confirmed.

The ratio of DXA-measured fat mass and MRI-measured adipose tissue volume

Several studies reported whole-body fat mass measured by DXA and whole-body adipose tissue volume measured by MRI before and after weight loss interventions.[7-9] The fat fraction percentage of adipose tissue was calculated by dividing the mass of fat measured by DXA by the mass of adipose tissue measured by MRI. One of the studies examined the effects of very low-calorie diet on body composition in men and women.[7] After three months of a weight loss intervention (Δ -8.1 kg (-8.0%) body mass in women and Δ -12.6 kg (-11.4%) body mass in men), they measured the changes in body fat (DXA) and adipose tissue volume (MRI) of the whole body. For example, MRI-measured whole-body adipose tissue volume was 47450 cm^3 (43.5 kg when adipose tissue mass was calculated using a density of 0.916 g/cm^3)[10] before weight loss and 40680 cm^3 (37.3 kg using the same conversion) after weight loss in women (n = 55). In contrast, DXA-measured total body fat mass was, respectively, 41.9 kg and 36.4 kg before and after weight loss. The calculated percentage of fat mass to adipose tissue mass was 96.5% before weight loss and 97.7% after weight loss (Δ 1.2%). The men's values calculated by the same process were 93.3% and 90.0%, respectively (Δ -3.3%). Similar results were observed in other studies (Table 1) suggesting that the weight loss-induced change in fat fraction percentage of adipose tissue is relatively small. In addition, the reason why the baseline values of adipose tissue fat fraction percentage are high is probably because DXA-measured fat mass also contains fat in tissues and organs other than adipose tissue. After weight loss, the DXA estimate includes the loss of fat in tissues and organs (i.e. muscle and liver) other than adipose tissue. By contrast, MRI quantifies the volume change (converted to adipose tissue mass) of adipose tissue (i.e. subcutaneous and visceral) only. Therefore, it might be expected that the fat fraction percentage would decrease significantly after weight loss, due to the DXA measurement including fat loss other than from adipose tissue. However, such a phenomenon was not clearly confirmed. These results suggest that the absolute amount of fat mass contained in tissues other than adipose tissue is relatively small compared to adipose tissue alone. The loss of fat in these organs/tissues after weight loss[11], likely has little influence on the change in the adipose tissue fat fraction percentage.

The chemical shift-based water-fat separation methods

MRI using chemical shift-based water-fat separation provides fat fraction percentages of adipose tissue in healthy humans in vivo. One study reported the fat fraction percentage of white adipose tissue measured before and after bariatric surgery.[11] Mean body mass decreased by 18.1 kg (-18.8% of body mass) after 6 months and 28.2 kg (-29.3% of body

Table 1 Change in fat fraction percentage in white adipose tissue before and after weight loss

	Study Protocol		Participant	Body mass (kg)			Fat fraction (%)		
Author [reference #]	Method	Weight loss	(period *)	Pre	Post	Δ change	Pre	Post	Δ change
Entenman et al [6]	Biopsy	CR	Subj E (M2)	89.1	80.7	-8.4	85.7	78.0	-7.7
	Biopsy	CR	Subj B (M4)	101.5	86.6	-14.9	79.2	62.3	-16.9
Bosy-Westphal et al [7]	MRI & DXA	VLCD	55W (M3)	101.1	93.0	-8.1	96.5	97.7	1.2
	MRI & DXA	VLCD	17M (M3)	111.0	98.4	-12.6	93.3	90.0	-3.3
Pourhassan et al [8]	MRI & DXA	LCD	17MW (M23)	NR	NR	NR	78.8	83.1	4.3
Lee & Kuk [9]	MRI & DXA	AE	14B (M3)	107.7	106.3	-1.4	92.5	94.0	1.5
	MRI & DXA	RE	14B (M3)	98.7	98.7	0	93.3	94.4	1.1
Hui et al [11]	WF MRI	BS	12MW (M6)	96.1	78.0	-18.1	84.4	79.9	-4.5
	WF MRI	BS	12MW (M12)	96.1	67.9	-28.2	84.4	77.2	-7.2

AE, aerobic exercise; B, boys; BS, bariatric surgery; CR, calorie restriction; DXA, dual-energy x-ray absorptiometry; LCD, low calorie diet; M, men; MW, men and women; MRI, magnetic resonance imaging; NR, not reported; RE, resistance exercise; VLCD, very low calorie diet; WF MRI, water-fat magnetic resonance imaging; W, women

* The numbers in parentheses are the intervention period and the unit is months

mass) after 12 months of bariatric surgery. Before surgery, the fat fraction percentage of white adipose tissue was 84.4%, and that decreased to 79.9% after 6 months (Δ -4.5%) and 77.2% after 12 months of bariatric surgery (Δ -7.2%) (Table 1). Unfortunately, we were unable to find any other studies that have examined this topic.

CONCLUSION AND FUTURE TASKS

Very few studies were found that reported changes in adipose tissue fat content with weight loss. At this time, we reported changes in adipose tissue fat content using three different processes but a consistent trend was not found. As a result, we were unable to conclude how much adipose tissue fat content changes after weight loss. We have previously estimated changes in FFM associated with gastric bypass surgery when correcting for adipose tissue-derived fat-free components.[5] We found that FFM loss was smaller after correcting for the fat-free component of adipose tissue when compared to the FFM loss measured by DXA. Furthermore, the degree of reduction in the evaluated FFM varied with the two different models (i.e. a model that does not change before and after weight loss and a model in which the fat content percentage decreases after weight loss) of changes in the adipose tissue fat content utilized.[5] If DXA or a densitometric method is used, it is necessary to accurately determine and calculate the change in the fat-free component of adipose tissue for determining the actual loss of FFM. However, even if the baseline values before weight loss can be predicted,[4,12] further research is needed to determine how much the fat fraction percentage changes in relation to weight loss.

Compliance with ethical standards

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