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## Fat-free mass change to weight change ratio during refeeding following lung transplantation

**Abstract** Malnutrition occurs frequently prior to lung transplantation (LTR), but patients gain weight after LTR. The study aimed to determine the ratio changes of fat-free mass ( $\Delta$ FFM): changes of body weight ( $\Delta$ BW) during refeeding. A total of 37 LTR patients were measured for weight and FFM and body fat by bioimpedance analysis at 1 month post-LTR, then annually for 3 years. Linear regressions determined the ratio  $\Delta$ FFM: $\Delta$ BW during refeeding.  $\Delta$ FFM was: year-1= $1.822+0.389 \cdot \Delta$ BW,  $r^2=0.397$ ; yr-2= $0.611+0.246 \cdot \Delta$ BW,  $r^2=0.441$ ; yr-3= $-0.17+0.208 \cdot \Delta$ BW,  $r^2=0.319$ . Refeeding during year-1 in thin subjects resulted in a ratio  $\Delta$ FFM: $\Delta$ BW of 0.389, whereas the change in ratio  $\Delta$ FFM: $\Delta$ BW during year-2 and 3 was 0.246 and 0.208, respectively. Refeeding resulted in a larger ratio  $\Delta$ FFM: $\Delta$ BW in thin subjects versus normal and overweight subjects. Thus, refeeding in underweight LTR patients is geared to normalizing depleted FFM, whereas later FFM gains were similar to FFM gains in normal and overweight subjects.

**Key words** Bioelectrical impedance analysis (BIA) · Body composition · Fat-free mass · Body fat mass · Lung transplantation · Nutritional assessment

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### Introduction

Lung transplant patients are often malnourished prior to lung transplantation (LTR), but gain weight rapidly after LTR. The etiology of weight loss in pulmonary disease is multifactorial and includes altered metabolism [1], presence of inflammatory mediators [2], and alterations produced by treatment and exacerbation of the disease [3]. Weight gain is common following heart [4] and liver transplant [5], however, no data are available in LTR patients. Although some weight gain is desirable, excessive gain in body fat should be avoided.

Refeeding after energy deprivation has been shown to increase fat-free mass (FFM) [6, 7]. Keys et al. [8] found a prompt regain in FFM and body fat after semi-starvation. However, few studies have evaluated the change in FFM to body weight changes ( $\Delta$ FFM: $\Delta$ BW) in healthy subjects and none has reported these changes in LTR patients. The aim of this study was to determine the ratio  $\Delta$ FFM: $\Delta$ BW during refeeding following LTR.

### Subjects and methods

Body composition was measured in 37 LTR patients at 1 month and 1, 2, and 3 years post-LTR. Thirty-seven healthy volunteers, matched for age ( $\pm 2$  years) and height ( $\pm 2$  cm), were used as controls. Informed consent was obtained from subjects before being placed on the LTR waiting list.

Body height was measured to the nearest 0.5 cm and body weight was measured to the nearest 0.1 kg on a balance beam scale. Body composition was determined by 50 kHz bioelectrical impedance analysis (BIA) as previously described [9] and validated [10, 11].

FFM was calculated using a previously validated multiple regression BIA equation [11]:  $FFM = -4.104 + (0.518 \cdot \text{height}^2 / \text{resistance}) + (0.231 \cdot \text{weight}) + (0.130 \cdot \text{reactance}) + [(4.229 \cdot \text{sex} (\text{men}=1, \text{women}=0))]$ . Cross-validation of BIA with DXA was excellent,

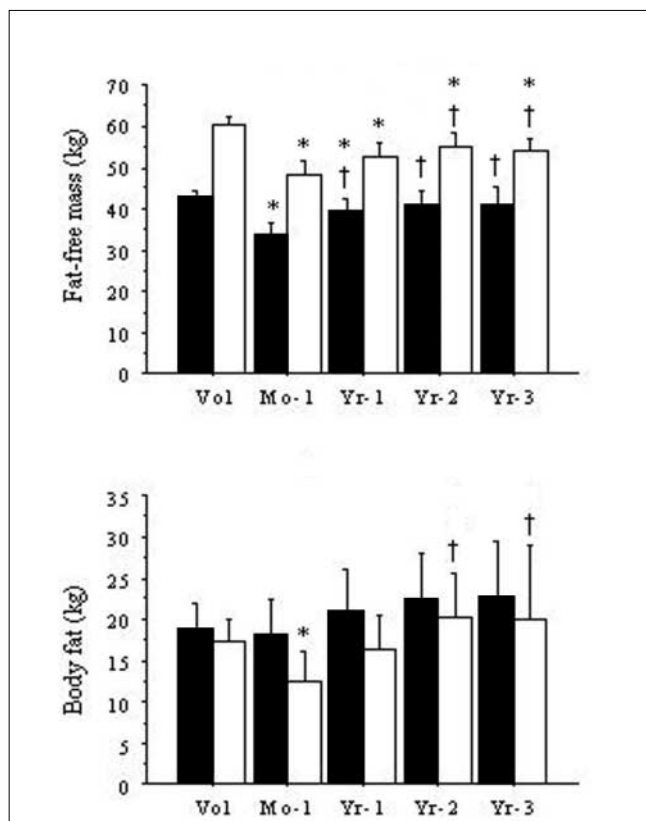
$r=0.986$ ,  $SEE=1.72$  kg, technical error 1.74 kg. This same BIA equation was also validated in elderly subjects [12] and transplant patients [13].

Statistical analysis

Descriptive statistics were calculated for height, weight, % ideal body weight, BMI, and body composition parameters and are expressed as mean±standard deviation. Unpaired *t* tests were used to test differences between pre-LTR and selected post-LTR measurements at 1 month and 1, 2, and 3 years. Simple linear regressions were calculated between weight change and FFM change and body fat change. Statistical significance was set at  $p<0.05$  for all tests.

Results

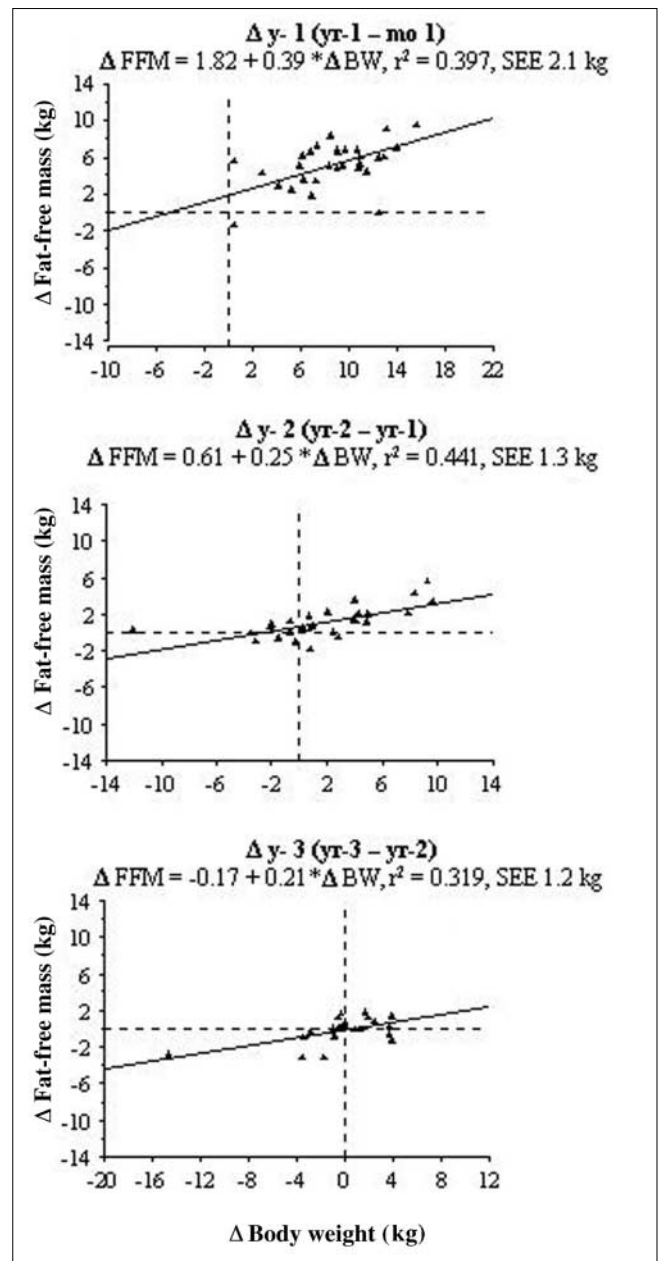
Patients had significantly lower weight and BMI at 1-month post-LTR evaluation than volunteers (data not shown). FFM was significantly lower throughout the study period in men and during the first year in women (Fig. 1). FFM was significantly higher at 1 year in women and 2 and 3 years post-



**Fig. 1** Fat-free mass (*top*) and body fat (*bottom*) in kg in female ■ and male □ volunteers and patients at 1 month and 1, 2, and 3 years. \*  $p<0.05$  vs. Vol; †  $p<0.05$  vs. Mo-1

LTR in men and women than at 1 month (Fig. 1). BF was significantly lower at 1 month after LTR in male patients than in volunteers, and significantly higher at 2 and 3 years than after 1 month in men. The weight gain after LTR resulted in FFM and body fat gain.

Figure 2 shows the  $\Delta FFM$  in comparison with  $\Delta BW$ . The  $\Delta FFM$  increased by 0.39, 0.25, and 0.21 kg for each kilogram of  $\Delta BW$  during years 1, 2 and 3, respectively. The  $\Delta FFM$  was higher (39% of weight) during year 1 than



**Fig. 2** Correlations between changes in body weight and ( $\Delta BW$ ) fat-free mass ( $\Delta FFM$ ) during year 1 (*top*), year 2 (*middle*), and year 3 (*bottom*). The respective FFM changes are expressed in relation to body weight changes. The FFM change was higher (39% of weight) during year 1 than during year 2 (25%) or year 3 (21%)

during year 2 (25%) or year 3 (21%). From these results we may deduce that an increase in weight resulted in an increase in FFM.

## Discussion

The aim of this study was to determine the  $\Delta\text{FFM}:\Delta\text{BW}$  during refeeding following LTR. Significant FFM increases were noted following LTR. Forbes [14] estimated the expected  $\Delta\text{FFM}:\Delta\text{BW}$  to be 0.48 for thin subjects and 0.26 for moderately obese subjects. Linear regressions (Fig. 2) between  $\Delta\text{FFM}$  and  $\Delta\text{BW}$  in our subjects showed a change of 0.39 and 0.25 kg FFM per kg weight change during year 1 and year 2, respectively. Thus, the FFM increases following LTR were in the expected ranges of change noted during recovery from energy deprivation. FFM to weight gain rates were higher in the early versus later recovery period, whereas higher rates of body fat to weight change were noted during year 2 and year 3 compared to year 1 (data not shown).

Refeeding after energy deprivation has been shown to increase FFM in anorexia nervosa [6], voluntary semi-starvation [8], and physical training with energy deficit [7]. Keys et al. [8] found a prompt regain in FFM and body fat after semi-starvation. The accretion of body fat occurred more rapidly than FFM. Both the Ranger Study [7] and the Minnesota Starvation Study [8] showed that FFM also returned to baseline later in the recovery process. A return to normal body composition was also noted 12 months after surgery in ulcerative colitis patients who had undergone colon and ileal resections [15]. Our study shows that a return to baseline body composition is possible after energy deprivation and illness in spite of treatment, such as calcineurine inhibitors, steroids and other drugs that might interfere with cell metabolism. Further research is required to determine the magnitude and contribution of the FFM to body weight gain in subjects who are ill.

## Study limitations

The measurement of BIA is occasionally criticized. In this study, simultaneous measurement by BIA and DXA showed a mean bias of  $-0.4 \pm 1.5$  kg, range  $-3.9$ – $3.4$  kg,  $r=0.987$ ,  $\text{SEE}=1.5$  kg. Therefore, there is good agreement between BIA and DXA.

## Conclusions

Refeeding resulted in larger  $\Delta\text{FFM}:\Delta\text{BW}$  in thin subjects than in normal and overweight subjects. Thus, it appears that

refeeding in underweight transplant patients is geared to normalizing depleted FFM, whereas later FFM gains are similar to FFM gains in normal and overweight subjects.

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