An approach to functional body composition during weight changes: Relationship between detailed body composition, resting energy expenditure, insulin resistance and sub-maximal oxygen consumption

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Accurate assessment of body composition and its changes in response to nutrition, development, inflammation, overweight and wasting disease is a precondition for understanding changes in metabolism and health. It is of particular interest to identify the relationships between individual body components and their associations with metabolic risk factors likes insulin resistance and resting energy expenditure. The present thesis therefore investigated 1. the composition of weight loss and weight gain using different methods including the gold standard, that is, the 4C-model, 2. the associations between changes in detailed body composition during long-term weight changes with REE and insulin resistance 3. the impact of detailed body composition on aerobic fitness to address whether fat-free mass (FFM), fat mass (FM) and their regional components have independent effects on sub-maximal oxygen consumption ($VO_{2submax}$).

1. There was a considerable bias between the body-composition data obtained by the individual methods. When compared with the 4C-model, mean bias of deuterium dilution (D_2O) and densitometry was explained by the erroneous assumption of a constant hydration of FFM, thus, changes in FM were underestimated by D_2O but overestimated by densitometry. Because hydration does not normalize after weight loss, all 2 component models have a systematic error in weight-reduced subjects. The bias between 4C-model and dual X-ray absorptiometry (DXA) was mainly explained by FM% at baseline whereas FFM hydration contributed to additional 5%. Comparing FFM and FM, proportionally more FFM was lost during weight loss than was gained during weight gain.

2. With weight gain, skeletal muscle, liver, kidney masses and several adipose tissue depots increased except for visceral adipose tissue (VAT). After adjustments for FM and FFM, resting energy expenditure (REE) decreased with weight loss (by 0.22 MJ/d), and increased with weight gain (by 0.11 MJ/d). In a multiple stepwise regression analysis, changes in skeletal muscle, plasma T3 and kidney masses explained 34.9%, 5.3% and 4.5% of the variance in changes in REE. Reduction in subcutaneous adipose tissue (SAT) rather than VAT was associated with the improvement of insulin sensitivity with weight loss. Weight gain had no effect on insulin resistance.

3. There was a strong association between $VO_{2submax}$ and FFM, and all organ masses except for heart. FFM and skeletal muscle mass accounted for 34.8 % of the variance in $VO_{2submax}$. In addition, SAT of arms and legs explained additional 14.4%. FFM and FM explained 71.3% of the variability in REE. Including the compositions of FFM and FM, the explained variance in REE increased by about 5.8%; skeletal muscle mass explained 70.0% of the variance in REE and kidney and liver masses explained additional 7.1%. Taking into account body composition, $VO_{2submax}$ did not add to the variance in REE.

In conclusion, 1. to assess changes in body composition associated with weight changes, only the 4C-model and magnetic resonance imaging (MRI) can be used with confidence, 2. beyond a 2-compartment

model, detailed changes in organ and tissue masses further add to explain changes in REE and insulin resistance, 3. FFM is a determinant of both, REE and $VO_{2submax}$. Despite the significant correlation between REE and aerobic fitness, $VO_{2submax}$ did not add to the variance in REE. However, FM added to the variance in REE, whereas SAT at extremities added to the variance in $VO_{2submax}$ only.