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# Effects of Reductions of Body Fat and Regional Adipose Tissue on Glucose and Lipid Metabolism Among Eldery Japanese

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**SUMMARY** : To evaluate effects of improvement of obesity on glucose and lipid metabolism, changes of body weight, skinfolds and biochemical parameters in glucose and lipid metabolism were examined through a six month health education on excercise and diet. Subjects were 20 men and 36 women aged from 48 to 87, who had overweight and/or glucose intolerance. Weight, relative weight and fat mass were significantly reduced after the program in both sexes. Circumference ratios were reduced only in women. The significant reduction of skinfold was found at the suprailiac in men, and at regions of upper body in women. The reduction of weight was associated with those of skinfolds in either sex. Fasting serum glucose in both sexes and serum insulin in men significantly decreased after the program. Statistical analyses revealed that improvements of glucose metabolism in men were contributed by decreases of skinfolds at abdominal and suprailiac regions. The increase of HDL was related to the decreases of fat mass in men and of abdominal-hip ratio in women. These findings indicate that excercise and/or dietary control are effective on the improvements of metabolic aberrations, and that measurements of regional skinfolds are important for estimating changing risks with the reduction of weight.

## INTRODUCTION

Obesity which is frequently associated with aberrations in glucose and lipid metabolism has been reported to be a high risk factor for non-insulin-dependent diabetes mellitus (NIDDM), cardiovascular diseases and stroke etc.[5) 15) 19)] The degree of obesity has been estimated by relative weight to height or ratio of fat mass to non-fat-mass or weight. Measurements of adipose tissue mass in different regions have been also used for estimating the extent and characteristic of obesity. Recent studies have indicated that regional distribution of adipose tissue is closely related to various metabolic complications.[14)18)] Vague[21)] first classified obesity as upper body obesity or lower body obesity by brachio-femoral adipomuscular ratio (AMR) and postulated that the former, a common type in male (android type) has higher risk for metabolic aberrations of obese state than the latter, being common in female (gynoid type). Furtheremore, abdominal or central type of obesity judged by waist /hip circumference ratio (WHR ) or skinfold of abdomen has been reported to be more susceptible to the effect of excess body fat on glucose metabolism, such as insulin resistance, hyperinsulinemia and glucose intolerance.[9) 12)] High lipolytic activity in abdominal subcutaneous fat, being closely related to visceral fat, has been expected as a cause of large effects on glucose and fat metabolism in abdominal type of obesity.[3) 4)]

Recently, according to the development of aging society, health promotion program aiming to prevent diabetes mellitus and cardiovascular diseases by weight control has been carried out in many communities of Japan. It has been reported that the reduction of weight by physical training and /or dietary control improve metabolic abberations.[1) 8) 10) 17)] Most of previous works on the effects of reduction of weight had been done with young or middle aged Caucasians and there is little systematic study on elderly Japanese who presumably have different somatotypes and distributions of adipose tissues, as well as differences in lifestyles from Caucasians.

The present study, based on a health promotion program for the prevention of diabetes mellitus in a community, aims to evaluate the effect of reduction of weight on glucose and lipid metabolism via changes of content and distribution of regional adipose tissues, with a special reference to sex difference.

## SUBJECTS & METHODS

*Subjects* :

A total of 56 subjects, 20 men and 36 women, aged between 48 to 87 years, living on the Oshima island in Nagasaki Prefecture were studied. On health examination in the summer of 1986, carriers of high risk factors for diabetes mellitus were selected by the following criterias ; glucose intolerance (fasting glucose level in serum was over 110 mg/100ml) ; obesity (BMI ; weight (kg)/height (m)$^2$), was over 25 in men and 28 in women : the percentage of fat mass to weight (%FT) was over 18 in men and over 26 in women). Ninety-five of 239 men and 103 of 385 women were selected by the above criterias, and were recommended to join the health promotion program with the aims to prevent diabetes mellitus by bodily exercise and dietary control. Among 117 participants of the program, men and women whose data were completely collected were subjects in the present study.

*Health promotion program* :

Health education was carried out once a month for six months under the collaboration of medical doctors, public health nurses and nutritionists. The content of health education was to promote the knowledge and practice for exercise (walking for over 1 hour everyday) and dietary control (30 kcal/kg of ideal body weight/day). At the start and the end of the program, anthropological and biochemical measurements were carried out, and ratio of the value at the start and at the end was used for estimating the change through the program.

*Anthoropometry* :

Height and weight (WT) were measured by routine methods and BMI was calculated. Circumference in the standing position was measured at the following levels ; the smallest region over the subcostal trunk (waist ; WAT), the umbiricus (abdomen ; ABD) and the widest region over the great trochanters (hip ; HIP), and ratios of WAT/HIP (WHR) and ABD/ HIP (AHR) were calculated. Skinfold thickness was measured by a Eiken type caliper at the following 7 sites ; the triceps (TC), the subscapular (SS), chest (CH), the axillar (AX), the suprailiac (SI), abdomen (AB) and thigh (TH). The percentage of fat mass (%FT) by Pollock's formula[6) 7)] and ratio of TC over TH (TTR) were calculated.

*Biochemical measurements* :

On serum collected at fasting condition, biochemical parameters in fat and glucose metabolism were measured by the following methods ; glucose (GLU) by OTB method (Glucose-Test, Wako, Osaka), insulin (IRI) by radioimmunoassay (IRI 'EIKEN', Eiken, Tokyo), high density lipoprotein cholesterol (HDL) by heparin-manganate combination precipitation method (HDL-Cholesterol-Test, Wako, Osaka), triglyceride (TRG) by enzyme method (TG 2, Daiichi, Tokyo), and total cholesterol (TCL) by modified o-phthalein-aldehyde method (Cholesterol B-test, Wako, Osaka). Furthermore, glucose tolerance was tested by oral administration of 75g glucose (OGTT). Delta-IRI (dIRI) and insulinogenic index (II) were calculated by the following formulas ; dIRI= (IRI at 30 min. after OGTT)-(basal IRI) ; II=dIRI/ (GLU at 30 min. after OGTT-basal GLU).

*Data processing* :

Statistical analyses were carried out on the obtained data by ANALYST (Analyzer for Statistical Data, FACOM, Tokyo ) in the Information Center of Nagasaki University. On statistcal analysis, ratios in anthoropological and biochemical measurements were transformed into natural logarithm.

## RESULTS

*1. Changes of anthropological measurements by the health education program.*

In both sexes, body weight and BMI were significantly reduced by the six-month program (Table 1). According with the reduction of body weight, all the skinfolds became thinner in both sexes but the pattern of reduction was differently characterized by sex (Fig. 1) : the reduction in women was large at the regions in the upper body, such as SS, CH and AX, whereas that in men was manifest in the lower body, such as AB and TH. Moreover, the reduction of SI was greater in women than in men. These changes of skinfolds acted on changes of body composition and ratio of skinfold ; %FT was significantly reduced in both sexes ($p<0.05$ in men, $p<0.001$ in women) but TTR significantly increased only in women (Table 1). Although all the circumferences became to be smaller in both sexes, significant differences

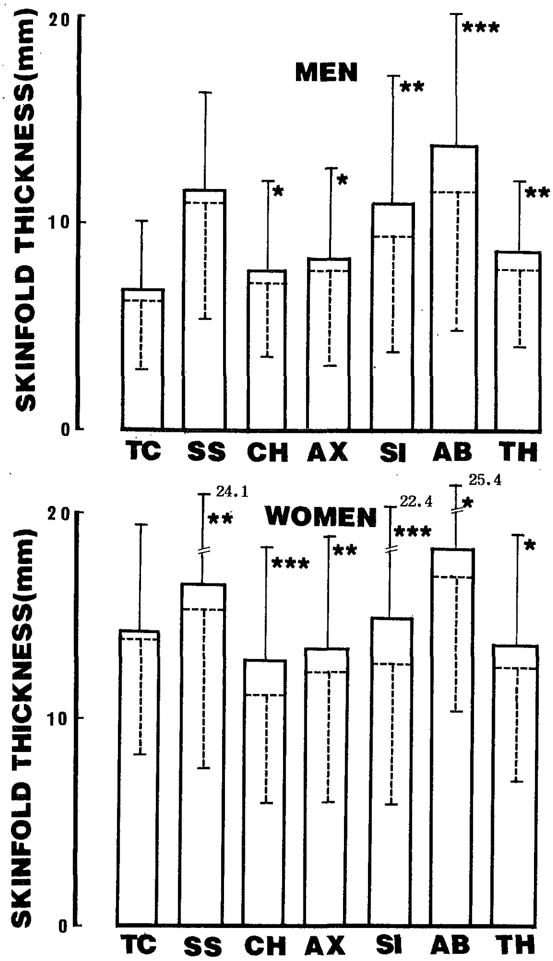


Fig. 1. Comparisons of skinfold thicknesses before (—) and after (···) the health program (TC : triceps, SS : subscapular, CH : chest, AX : axillar, SI : suprailiac, AB : abdomen, TH : thigh).

Table 1. Comparisons of anthropological measurements before and after a 6 month health education program (Mean±S. D.).

| | men (n=20) | | women (n=36) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Age (years) | 67.0±8.7 | — | 64.4±8.7 | — |
| Height (cm) | 158.4±5.7 | — | 147.5±5.4 | — |
| Body Weight (kg) | 56.6±11.2** | 55.0±10.5 | 52.7±10.5*** | 51.3±10.6 |
| Body Mass Index | 22.5±3.7 ** | 21.8±3.4 | 24.0±4.2 *** | 23.4±4.2 |
| Percent Fat (%) | 14.5±4.0 *** | 13.5±3.8 | 19.1±4.8 *** | 17.8±4.9 |
| Abdomen/Hip circumferences ratio | 0.91±0.07 | 0.91±0.07 | 0.93±0.07 | 0.93±0.08 |
| Waist/Hip circumferences ratio | 0.89±0.06 | 0.88±0.09 | 0.85±0.07* | 0.83±0.07 |
| Triceps/Thigh skinfolds ratio | 0.79±0.21 | 0.86±0.29 | 1.06±0.31* | 1.16±0.40 |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ : by paired t-test

were found only in women at, WAT and HIP (Fig.2). Because of larger reduction in WAT (−2.2cm) than that in HIP (−1.3cm), WHR in women was significantly reduced (Table 1).

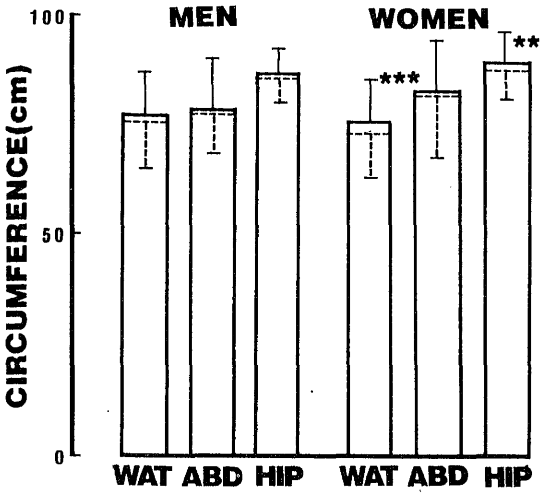


**Fig. 2.** Comparisons of circumference before (—) and after (···) the health program (WAT : waist, ABD : abdominal, HIP : hip).

*2. Relationships of weight reduction to change of skinfolds, circumference and body fat*

For evaluating effects of weight reduction on characteristics of obesity, simple correlation analysis was carried out (Table 2). The reduction of skinfold thickness was more significantly related with that of weight in women than in men : significant correlation coefficients between changes of WT and skinfold was observed at almost regions in women, but only at SI in men. Moreover, the decrease of %FT was more significantly related with that of weight in women ($p<0.001$) as compared with men ($P<0.05$).

**Table 2.** Correlation coefficients between changes of weight and body composition, circumference and skinfold.

| | men | women |
|---|---|---|
| Skinfold | | |
| r-TC | 0.22 | 0.50** |
| r-SS | 0.32 | 0.76*** |
| r-CH | 0.08 | 0.16 |
| r-AX | 0.28 | 0.49** |
| r-AB | 0.36 | 0.67*** |
| r-SI | 0.45* | 0.61*** |
| r-TH | 0.23 | 0.17 |
| Circumference | | |
| r-WAT | 0.09 | 0.47** |
| r-ABD | 0.52* | 0.33 |
| r-HIP | 0.49 | 0.43* |
| r-WHR | −0.05 | 0.19 |
| r-AHR | 0.31 | 0.15 |
| r-TTR | 0.11 | 0.34 |
| r-%FT | 0.56* | 0.68*** |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ abbreviations are indicators in the text.
r- : means ratio of values before and after the program

Significant correlations of the decrease of weight to circumferences were found at ABD and HIP in men, and WAT and HIP in women. However, none of the change in circumference ratios showed significant correlation to decrease of WT in both sexes. Results of stepwise multiple regression analysis also indicated that the reduction of WT in men was not contributed by any change of skinfolds (Table 3). In women, decreases of skinfolds in the upper body, SS and AX, significantly contributed to the reduction of WT.

**Table 3.** Results of multiple regression analysis for explaining changes of weight as a dependent variable by changes of 7 skinfolds at 7 sites as independent variables.

| Selected Variable | Multiple Regression Coefficient | Standard Coefficient |
|---|---|---|
| Men | | |
| Step 1 : r- SI | 0.44 | 0.42* |
| Women | | |
| Step 1 : r- SS | 0.75 | 0.73*** |
| Step 2 : r-AX | 0.78 | 0.27* |
| Step 3 : r-CH | 0.80 | −0.23 |

* $p<0.05$, ** $p<0.01$, *** $p<0.001$ r- : same in Table 2

*3. Changes in biochemical measurements and blood pressure by the health program*

On glucose metabolism, GLU in both sexes and IRI in men significantly decreased by the program (Table 4). Although individual variation was large, either II or dIRI increased in both sexes.

There was no statistically significant change on lipid metabolism in both sexes. However, large amounts of elevation of HDL were observed in either sex (9.8mg/100ml in men ; 3.9 mg/100ml in women). There was no significant change in systolic blood pressure (SBP) and diastolic blood pressure (DBP) of both sexes.

*4. Effects of reduction of obesity on biochemical measurements and blood pressures*

For evaluating effects of reduction of obese state on improvements of metabolic aberrations, two series of stepwise multiple regression analyses using each biochemical measurement as a dependent variable, were carried out.

On the results of analyses using changes of skinfolds at seven regions as independent variables, the obvious sex difference was found in the contribution of thinness of each regional skinfold to improvements in glucose metabolism (Table 5). The decrease of GLU, and increases of II and dIRI were significantly contributed

**Table 4.** Comparisons of biochemical measurements and blood pressure before and after a 6-month health education program (Mean±S. D.).

| | men (n=20) | | women (n=36) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Biochemical parameters | | | | |
| Glucose (mg/100ml) | 106.7±24.0** | 93.6±23.5 | 108.0±23.3** | 91.5±13.1 |
| Insulin (uU/ml) | 8.23±4.85* | 4.59±3.82 | 10.27±7.40 | 7.91±6.29 |
| Insulinogenic Index | 0.40±0.49 | 0.60±0.55 | 0.60±0.55 | 0.74±1.10 |
| Delta-Insulin | 27.6±25.5 | 32.6±24.4 | 36.9±26.8 | 41.7±42.5 |
| Total cholesterol (mg/100ml) | 177.6±44.0 | 173.1±46.0 | 215.4±38.9 | 207.1±44.1 |
| Triglyceride (mg/100ml) | 74.7±25.3 | 66.3±42.4 | 79.2±47.4 | 83.7±68.1 |
| HDL cholestlrol (mg/100ml) | 45.4±13.7 | 55.2±24.1 | 48.9±18.6 | 52.8±26.9 |
| Blood Pressure | | | | |
| Systolic Pressure (mmHg) | 141.8±16.8 | 143.8±21.7 | 140.2±22.0 | 145.4±15.0 |
| Diastolic Pressurl (mmHg) | 80.5±11.3 | 77.0±12.8 | 81.6±12.0 | 80.3±10.1 |

*p<0.05, **p<0.01, ***p<0.001 : by paired t-test

**Table 5.** Results of multiple regression analysis for explaining change of each biochemical paremeter as a dependent variable using changes of skinfold thicknesses at 7 sites as independent variables

| | MEN | | | WOMEN | | |
|---|---|---|---|---|---|---|
| Dependent Variable | Selected Variable | Multiple Regression Coefficient | Standard Coefficient | Selected Variable | Multiple Regression Coefficient | Standard Coefficient |
| r-GLU | Step 1 : r-AB | 0.39 | 0.51* | Step 1 : (−) | | |
| r-II | Step 1 : r-SI | 0.35 | 0.51* | Step 1 : (−) | | |
| | Step 1 : r-AX | 0.47 | −0.34 | | | |
| r-IRI | Step 1 : (−) | | | Step 1 : (−) | | |
| r-dIRI | Step 1 : r-SI | 0.37 | 0.46* | Step 1 : (−) | | |
| | Step 2 : r-TC | 0.49 | −0.34 | | | |
| r-TCL | Step 1 : (−) | | | Step 1 : (−) | | |
| r-TGR | Step 1 : (−) | | | Step 1 : r-AX | 0.31 | 0.31 |
| r-HDL | Step 1 : r-SS | 0.40 | −0.45* | Step 1 : r-AB | 0.33 | −0.33 |
| | Step 2 : r-AB | 0.53 | −0.45* | | | |
| | Step 3 : r-SI | 0.63 | −0.37 | | | |
| r-SBP | Step 1 : (−) | | | Step 1 : (−) | | |
| r-DBP | Step 1 : r-AX | 0.40 | −0.40 | Step 1 : (−) | | |

*p<0.05, **p<0.01 r- : same in Table 2
(−) : nothing is selected by stepwise multiple regression analysis

by the thinness of skinfolds in the lower body, such as AB and SI in men, but none of the improvements in women was significantly related to the change of skinfold itself. On lipid metabolism, the increase of HDL in men was contributed primarily by the decrease of SS and secondary by that of AB.

On the contribution of changes of circumference ratios, BMI and %FT on metabolic aberrations, increases of IRI in men and d-IRI in women were contributed by the decrease of AHR in men and that of BMI in women, respectively (Table 6). Increases of HDL were significantly depended on decrease of %FT in men and that of AHR in women. The elevation of SBP in women was related to the decrease of WHR.

## DISCUSSION

From a public health viewpoint, it is worth to mention that body weight, especially in fat mass, was significantly reduced and metabolic aberrations were improved by a six-month health education program. This fact indicates that the health educations for the promotion of excercise and/or dietary control are effective to the improvement of metabolic implications even among the elderly living in rural communities.

The sex difference in the present study on the thinning of skinfolds, a proportional decrease in men and a large decrease in the upper body in women, is coincident with previous findings that the peripheral or upper body type of obesity in women is more easily improved than the central or abdominal type.[12] Although the kinetics of such sex difference in obesity are speculative, roles of sexual hormones have been considered.[11) 13) 16) 22] It is intersting that sex difference which has been reported on young or middle aged (pre-menopausal) Caucasians, is observed in the elderly (post-menopausal) Japanese.

It has been reported that physical exercise decreases particular regions of skinfolds having high lipolytic activity, such as the abdomen, whereas dietary control induces a proportional change of skinfold to the initial value.[1) 2) 10] The extents of practise in exercise and /or dietary control may modify the different patterns of skinfold reduction between sexes.

**Table 6.** Results of multiple regression analysis for explaining change of each biochemical parameter as a dependent variable using changes of BMI, %FT and ratios of circumferences and skinfolds as independent variables

| Dependent Variable | MEN Selected Variable | MEN Multiple Regression Coefficient | MEN Standard Coefficient | WOMEN Selected Variable | WOMEN Multiple Regression Coefficient | WOMEN Standard Coefficient |
|---|---|---|---|---|---|---|
| r-GLU | Step 1 : (−) | | | Step 1 : r-WHR | 0.35 | −0.32 |
| | | | | Step 2 : r-AHR | 0.43 | −0.25 |
| r-II | Step 1 : (−) | | | Step 1 : r-BMI | 0.38 | −0.38* |
| r-IRI | Step 1 : r-AHR | 0.44 | −0.48* | Step 1 : r-AHR | 0.28 | −0.28 |
| r-dIRI | Step 1 : (−) | | | Step 1 : r-BMI | 0.34 | −0.30 |
| r-TCL | Step 1 : (−) | | | Step 1 : (−) | | |
| r-TGR | Step 1 : (−) | | | Step 1 : r-BMI | 0.33 | 0.33 |
| r-HDL | Step 1 : r-%FT | 0.46 | −0.46* | Step 1 : r-AHR | 0.38 | −0.34* |
| | | | | Step 2 : r-BMI | 0.51 | −0.33 |
| r-SBP | Step 1 : r-WHR | 0.34 | −0.34 | Step 1 : r-WHR | 0.48 | 0.44** |
| | | | | Step 2 : r-BMI | 0.53 | 0.24 |
| r-DBP | Step 1 : (−) | | | Step 1 : (−) | | |

* $p<0.05$, ** $p<0.01$ r- : same in Table 2 (−) : same in Table 5

Significant contribution of thinness of skinfolds at the central part,i.e., AB and SI to improvements of GLU, II and dIRI in men also coincides with previous reports that an accumulation of fat in the lower body is high risk for aberrations in glucose metabolism.[9) 12)] The lack of significant contribution of the change of skinfold on glucose metabolism in women also supports the previous findings that the peripheral or upper body type of obesity in women may not be high risk for metabolic implications.[1)]

The most manifest finding on lipid metabolism is the increase of HDL through the program. It has been reported that the HDL level in serum is elevated by physical training.[20)] Greater extent of elevation of HDL in men as compared with that in women, may related to high frequency of physical excercise in men. Judging from significant relationships to the reductions of %FT and skinfolds at both the upper and lower body, i.e., SS and AB, the elevation of HDL seems to be related to the loss of body fat as a whole.

For assessing risks for obesity related metabolic aberrations, circumstance ratios, especially WHR, have been used as the most convenient indicator.[14)] In the present study, metabolic improvements were less related to reductions of circumference ratios than those in skinfolds themselves. This discrepancy from the previous reports may be explained in part by changing pattern of thinness of skifolds with the reduction of weight ; if the skinfold at each region decreases in proportion to the initial value, the ratio may not be greatly changed. This hypothesis also indicates that obesity related indicators for the assessment of risks have different meanings between cross-sectional and cohort observations. The changes in each skinfold thickness itself and the content of bodily fat as a whole seem to have more particular values for estimating changing risks in metabolic aberrations with the reduction of body weight.

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