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*Original Article*

# Altered abdominal fat distribution and its association with the serum lipid profile in non-diabetic haemodialysis patients

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**Abstract**

**Background.** Disturbances of lipid and carbohydrate metabolism may be associated with the distribution of abdominal adiposity. However, little is known about the alteration of abdominal adiposity and its association with the serum lipid profile in haemodialysis patients.

**Methods.** We evaluated the distribution of abdominal adiposity by using computed tomography and examined its relationship with the serum lipid profile in 92 non-diabetic haemodialysis patients and 80 control subjects with normal renal function. Since the mean body mass index (BMI) and total body fat mass were significantly lower in the haemodialysis patients than in the control subjects, the subcutaneous abdominal fat area and the visceral fat area were standardized by body mass index and compared between the haemodialysis patients and the control subjects.

**Results.** Mean subcutaneous fat area/body mass index (SFA/BMI) was significantly lower, and mean visceral fat area/body mass index (VFA/BMI) was significantly higher in the haemodialysis patients (SFA/BMI, $2.40 \pm 0.12$; VFA/BMI, $2.28 \pm 0.15$) than in the control subjects (SFA/BMI, $3.75 \pm 0.21$, $P < 0.01$; VFA/BMI, $1.65 \pm 0.15$, $P < 0.01$). Consequently, visceral fat area/subcutaneous fat area ratio was significantly higher in the haemodialysis patients ($1.05 \pm 0.07$) than in the control subjects ($0.46 \pm 0.04$, $P < 0.01$). A scattered plot of visceral fat area relative to BMI revealed that visceral fat area was higher in the haemodialysis patients than in the control subjects at any BMI level. A simple regression analysis showed that BMI, total body fat mass, subcutaneous fat area and visceral fat area were all associated with serum triglycerides and the atherogenic index, (total cholesterol–HDL cholesterol)/HDL cholesterol. Furthermore, a multiple regression analysis indicated that the visceral fat area was the best predictor for either the atherogenic index or triglycerides among these fat components.

**Conclusions.** These data indicate that haemodialysis patients exhibited a visceral fat accumulation irrespective of BMI, and this shift of abdominal adiposity might be associated with disturbance of the serum lipid profile in non-diabetic haemodialysis patients.

**Key words:** abdominal fat distribution; atherosclerosis; haemodialysis; lipid metabolism; visceral fat

## Introduction

Atherosclerosis is a serious complication in haemodialysis (HD) patients [1,2]. Previous investigations suggest that cardiovascular diseases are the major causes of death in HD patients [3–5], and these diseases are known to be closely related with metabolic abnormalities involving lipids and carbohydrates [6]. The serum lipid profile in chronic HD patients is characterized by an elevation in the levels of triglycerides and very low density lipoprotein (VLDL), and a decrease in the level of high-density lipoprotein (HDL) cholesterol [7]. Although the total cholesterol and low-density lipoprotein (LDL) levels may be within the normal range, the arteriosclerosis index (AI) is elevated because of the low HDL cholesterol level. Furthermore, chronic HD patients have been reported to have glucose intolerance and hyperinsulinaemia, partly due to insulin resistance [8]. Hypertension, a frequent complication in patients with chronic renal failure (CRF), is also associated with the progression of arteriosclerosis [9].

Attention has recently been paid to multiple risk factor syndromes such as syndrome X [10], deadly quartet syndrome [11] and visceral fat syndrome [12] in terms of the development of atherosclerosis in the general population. These syndromes include metabolic abnormalities associated with abdominal fat accumulation, glucose intolerance, hyperinsulinaemia, hyperlipidaemia and hypertension. These metabolic

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abnormalities are likely to be associated with the accumulation of visceral rather than subcutaneous abdominal adipose tissue in both obese and normal-weight subjects [12,13]. The development of cardiovascular disease is also irrespective of body weight in patients with the visceral fat syndrome [13].

While the metabolic abnormality characteristic of HD patients resemble those associated with these syndromes, there have been few reports concerning body fat distribution and its significance for metabolic disturbances in HD patients. Lee *et al.* [14] recently demonstrated that abdominal adiposity was not higher in HD patients than in control subjects, and abdominal adiposity might not play an essential role for dyslipidaemia and insulin resistance in leaner HD patients. However, they might have underrated the role of fat distribution in lipid metabolism because they did not distinguish between intra-abdominal fat accumulation and subcutaneous abdominal fat accumulation. Fernström *et al.* [15] reported that intra-abdominal fat increased during a 7.2 month follow-up investigation in patients undergoing continuous ambulatory peritoneal dialysis (CAPD). Those patients, however, received a carbohydrate overload through the peritoneal dialysate and, thus, might have experienced different metabolic consequences from those of HD patients. In this study, we examined the distribution of abdominal fat using X-ray computed tomography (CT) and investigated the relationship between visceral fat accumulation and lipid and glucose metabolic disturbances in non-diabetic chronic HD patients.

## Subjects and methods

### *Subjects*

Ninety-two patients (57 males and 35 females) undergoing HD due to various causes at Iwata City Hospital, and 80 control subjects (41 males and 39 females) with normal renal function participated in this study. Patients with diabetic nephropathy, patients treated with insulin or oral hypoglycaemic agents, and those who had been undergoing HD for less than 1 year were excluded from the study. None of the patients was taking lipid-modifying medications, corticosteroids, anabolic steroids, testosterone, oestrogen or progesterone. The HD patients were maintained on a regular HD prescription three times a week for 4–5 h, using hollow-fibre dialysers with a bicarbonate-buffered dialysate (Kindaly AF-3P, Fuso, Osaka, Japan; or AK-SOLITA, Shimizu, Shizuoka, Japan). The blood flow rate was in the range of 150–250 ml/min with a dialysate flow rate of 500 ml/min.

Blood samples for biochemical analysis were drawn during fasting. The serum or plasma was immediately transferred into plastic tubes and stored at $-82^{\circ}$C until analysed. Body weight was measured before and after each dialysis, the post-dialysis body weight served as the dry weight. Body mass index (BMI) was calculated from the formula: post-dialysis dry weight/height$^2$.

### *Measurement of the body fat mass and the abdominal fat distribution*

The body fat mass was measured with a BIA-101 bioelectrical impedance analyser (RJL, Clinton, MI, USA) in the supine position. The electrodes were placed at the upper extremity without an arteriovenous fistula and at the lower extremity. The formulae for calculating the body fat mass were modified from those that have been validated to correlate with measurements by dual-energy X-ray absorptiometry on HD patients [16,17]:

$$\text{Males: body fat mass (kg)} = \text{BW} - 0.55\ (\text{HT}^2/\text{R}) - 16.69$$

$$\text{Females: body fat mass (kg)} = \text{BW} - 0.55(\text{HT}^2/\text{R}) - 11.49.$$

Where BW is the body weight (kg), HT is the height (cm) and R is the impedance ($\Omega$).

The abdominal fat distribution was determined using CT. The X-ray film was traced by a scanner connected to a personal computer. The subcutaneous fat area (SFA) and the visceral fat area (VFA) were measured using the public-domain program, NIH-image (written by Wayne Rasband at the US National Institute of Health), at a level between the third and fourth lumbar vertebrae. The intra-abdominal fat mass, having the same density as the subcutaneous fat layer, is defined as the visceral fat.

### *Analytical procedures*

Serum triglycerides, total cholesterol and glucose were measured using standard laboratory techniques with an automatic analyser. Haemoglobin A1c was determined using the latex fixation method, while HDL cholesterol was measured by the precipitation method using magnesium phosphotungstate. The plasma insulin was assayed using a double antibody radioimmunoassay. The atherogenic index (AI) was calculated from AI = (total cholesterol − HDL cholesterol)/HDL cholesterol, and the pre-dialysis mean blood pressure (MBP) was determined from MBP = diastolic + (systolic − diastolic)/3. A single-pool urea kinetic model was used to calculate the protein catabolic rate (PCR) and the delivered dose of dialysis ($Kt/V_{urea}$) as described previously [18].

### *Statistical analysis*

Each value is presented as the mean ± SEM and differences between groups, except for triglyceride values, were analysed using the Student's *t*-test. Comparison of triglyceride values between the two groups was performed using the Mann–Whitney test because it was not normally distributed. Simple- and multiple regression analyses were applied to examine the relationship between body fat mass, SFA or VFA and various parameters. *P*-values $<0.05$ were considered statistically significant. All statistical calculations were performed with GB-STAT software (Dynamic Microsystems, Silver Spring, MD, USA).

## Results

The clinical profiles of the HD group and the age-matched control group are summarized in Table 1. Mean BMI and total body fat mass measured using a bioelectrical impedance analysis were significantly lower in the HD patients than in the control subjects. Mean blood pressure, triglycerides, the AI and insulin were significantly higher, while total cholesterol, HDL cholesterol and albumin were significantly lower in the HD patients than in the control subjects.

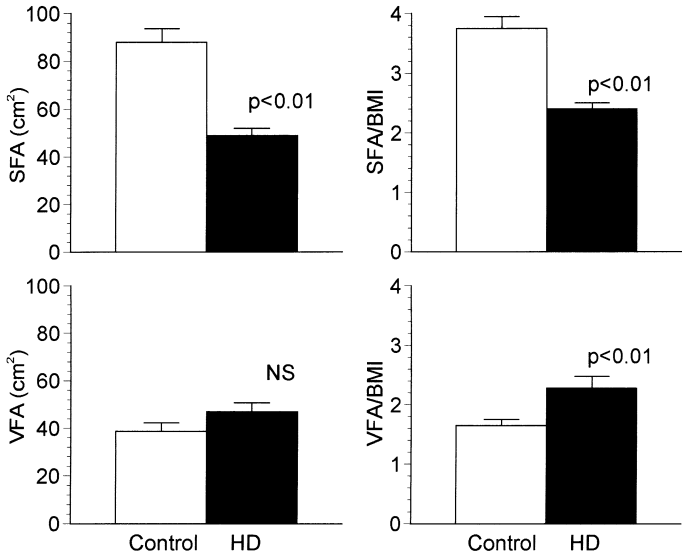


**Fig. 1.** Comparison of SFA, VFA, SFA/BMI and VFA/BMI between the control subjects and hemodialysis patients. Abbreviations: SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index; HD, haemodialysis. Data are presented as the mean ± SEM.

The mean SFA in the control subjects was significantly higher than that in the HD patients (Figure 1), whereas the mean VFA was not statistically different between the control subjects and the HD patients. Since there was a significant difference in BMI and total body fat mass between the control subjects and the HD patients, SFA and VFA were standardized by BMI in both groups. SFA/BMI for the control subjects was significantly higher than that for the HD patients (Figure 1). In contrast, VFA/BMI for the control subjects was significantly lower than that for the HD patients. The HD patients had a significantly higher V/S ratio, an index of intra-abdominal fat accumulation [19], than the control subjects (Figure 2). The correlation between BMI and SFA or VFA for both the control subjects and the HD patients is given in Figure 3. SFA and VFA were significantly correlated with BMI for both the control subjects and the HD patients. At any BMI value, VFA for the HD patients was higher than that for the control subjects.

Since the pattern of body fat distribution was reported to be somewhat different in males and females, we analysed the data for males and females separately. The results showed that the relationship between fat distribution and lipid profile for the controls and the HD patients was similar for both the males and the females.

The respective relationships of BMI, body fat mass, SFA or VFA with the various clinical variables for the HD patients are shown in Table 2. The data indicate that the AI and serum triglyceride level seem to have a close correlation with these fat-related parameters. A multiple regression analysis was thus applied to identify which fat parameter had the strongest relation-

**Table 1.** Characteristics of study population

| Variable | Control | HD | *P* |
|---|---|---|---|
| Male/Female | 41/39 | 57/35 | n.s. |
| Age (year) | 59.2 ± 1.6 | 57.5 ± 1.3 | n.s. |
| Duration of HD (years) | – | 10.2 ± 0.6 | – |
| BMI (kg/m$^2$) | 22.9 ± 0.3 | 19.6 ± 0.3 | < 0.001 |
| Body fat mass (kg) | 16.3 ± 0.6 | 10.6 ± 0.7 | < 0.001 |
| Mean blood pressure (mmHg) | 91.8 ± 1.9 | 107.9 ± 1.6 | < 0.001 |
| Total-cholesterol (mmol/l) | 5.10 ± 0.12 | 4.38 ± 0.09 | < 0.001 |
| HDL cholesterol (mmol/l) | 1.48 ± 0.04 | 1.24 ± 0.04 | < 0.001 |
| Atherogenic index | 2.63 ± 0.12 | 2.86 ± 0.13 | < 0.05 |
| Triglycerides (mmol/l) | 1.14 ± 0.05 | 1.33 ± 0.08 | < 0.05 |
| Fasting blood sugar (mmol/l) | 5.30 ± 0.12 | 5.39 ± 0.13 | n.s. |
| $HbA_1C$ (%) | 5.1 ± 0.1 | 5.2 ± 0.1 | n.s. |
| IRI (μU/ml) | 5.9 ± 0.7 | 18.1 ± 1.3 | < 0.001 |
| Albumin (g/l) | 43.3 ± 0.4 | 41.0 ± 0.5 | < 0.01 |
| PCR (g/kg/day) | – | 1.32 ± 0.03 | – |
| Kt/V | – | 1.33 ± 0.02 | – |

Abbreviations: HD, haemodialysis; BMI, body mass index; HDL, high-density lipoprotein; Hb, haemoglobin; IRI, immunoreactive insulin; PCR, protein catabolic rate; n.s., not significant. Data are presented as mean ± SEM.

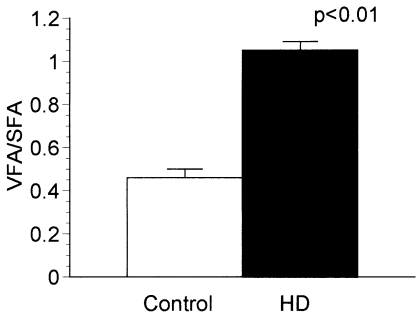


**Fig. 2.** Comparison of VFA/SFA between the control subjects and haemodialysis patients. Abbreviations: SFA, subcutaneous fat area; VFA, visceral fat area. Data are presented as the mean ± SEM.

ship with the AI and serum triglycerides (Table 3). VFA was found to be the best respective predictor for AI and triglycerides among the parameters analysed.

## Discussion

This study has demonstrated that intra-abdominal adiposity was significantly higher in the HD patients than in the control subjects of comparable BMI, while the mean subcutaneous abdominal adiposity was significantly lower in the HD patients than in the control subjects. Consequently, the visceral fat/subcutaneous fat ratio in the abdomen was significantly higher in the HD patients than in the control subjects. We also found that the visceral fat accumulation was associated with the serum lipid abnormalities in the HD patients.

Obesity has been recognized as a serious risk factor for mortality and morbidity for cardiovascular diseases in the general population [20]. We have also reported that being overweight is a risk factor for mortality and morbidity over 10 years in HD patients [21]. Recent studies have demonstrated that cardiovascular disease and its related mortality might be affected by not only the total amount of body fat, but also by the regional distribution of body fat. Kissebah *et al.* [22] have demonstrated, by measuring circumferences of the waist and hips, that upper-body obesity with a high waist–hip ratio was associated with abnormalities in lipid and carbohydrate metabolism. A subsequent epidemiological report showed that the abdominal fat accumulation increased the incidence of cardiovascular disease and death, and that the waist–hip ratio was a better index of complication to obesity than BMI or the subcutaneous fat thickness [23].

However, this classification for the regional distribution of obesity, the waist–hip ratio, is based on the distribution of subcutaneous fat, and the contribution of such intra-abdominal fat as omental and mesenteric adipose tissues was not considered. Borkan *et al.* [24] have developed a method for analysing abdominal fat distribution using CT, and could classify abdominal fat into subcutaneous and intra-abdominal fat masses. Visceral obesity, rather than subcutaneous obesity, has been reported to be closely correlated with such metabolic disorders as glucose intolerance, hyperinsulinaemia, hyperlipidaemia and hypertension [12,13,19,25,26]. The combination of such metabolic disorders, called insulin resitance–dyslipidaemic syndrome, is associated with an increased risk of cardiovascular disease [25].

The current study has demonstrated using a simple regression analysis that serum lipid levels were associated with BMI, body fat mass, SFA and VFA. However, the multiple regression analysis revealed that the VFA measured by CT was the best predictor of AI and serum triglyceride level. These data principally agree with those of previous studies evaluating the role of visceral obesity in lipid and carbohydrate metabolism in a general population.

The accumulation of intra-abdominal adipose tissue with higher lipolytic activity [27] is associated with the excess release of free fatty acid into the portal vein. Increased delivery of free fatty acid in the portal vein may result in reduced hepatic insulin clearance and increased hepatic glucose production [28]. Together with these mechanisms, the peripheral insulin resistance exacerbates hyperinsulinaemia in patients with visceral obesity [25]. Furthermore, abdominal adiposity is

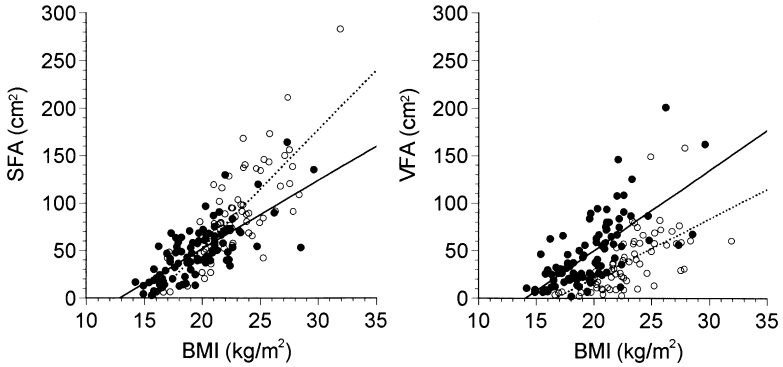


**Fig. 3.** Relationships of SFA or VFA with BMI for the control subjects and haemodialysis patients. SFA was significantly correlated with BMI in both the control subjects ($r=0.77$, $P<0.001$) and haemodialysis patients ($r=0.73$, $P<0.001$). VFA was also significantly correlated with BMI in both the control subjects ($r=0.60$, $P<0.001$) and haemodialysis patients ($r=0.69$, $P<0.001$). VFA in the haemodialysis patients was significantly higher than in the control subjects for any BMI value. Controls (○, dashed line); haemodialysis patients (●, solid line). Abbreviations: SFA, subcutaneous fat area; VFA, visceral fat area; BMI, body mass index.

**Table 2.** Simple correlation of BMI, body fat mass, SFA and VFA with clinical variables in haemodialysis patients

| Variable | BMI | | Body fat mass | | SFA | | VFA | |
|---|---|---|---|---|---|---|---|---|
| | *r* | *P* | *r* | *P* | *r* | *P* | *r* | *P* |
| Age | −0.12 | n.s. | 0.08 | n.s. | −0.03 | n.s. | −0.18 | n.s. |
| Duration of HD | −0.07 | n.s. | −0.10 | n.s. | −0.11 | n.s. | 0.19 | n.s. |
| Mean blood pressure | −0.05 | n.s. | −0.10 | n.s. | 0.06 | n.s. | 0.02 | n.s. |
| Total cholesterol | 0.20 | n.s. | 0.32 | <0.01 | 0.25 | <0.05 | 0.20 | n.s. |
| HDL cholesterol | −0.26 | <0.05 | −0.13 | n.s. | −0.18 | n.s. | −0.28 | <0.05 |
| Atherogenic index | 0.37 | <0.001 | 0.28 | <0.05 | 0.32 | <0.05 | 0.40 | <0.001 |
| Triglycerides | 0.25 | <0.05 | 0.27 | <0.05 | 0.19 | n.s. | 0.41 | <0.001 |
| Fasting blood sugar | 0.14 | n.s. | 0.14 | n.s. | 0.19 | n.s. | 0.02 | n.s. |
| $HbA_1c$ | 0.25 | <0.05 | 0.17 | n.s. | 0.17 | n.s. | 0.17 | n.s. |
| IRI | 0.07 | n.s. | 0.39 | <0.01 | 0.16 | n.s. | 0.21 | n.s. |
| Albumin | 0.10 | n.s. | −0.01 | n.s. | 0.09 | n.s. | 0.25 | <0.05 |
| PCR | 0.11 | n.s. | −0.01 | n.s. | −0.07 | n.s. | 0.04 | n.s. |
| Kt/V | −0.22 | n.s. | 0.19 | n.s. | 0.06 | n.s. | −0.16 | n.s. |

Abbreviations: HD, haemodialysis; BMI, body mass index; HDL, high-density lipoprotein; Hb, haemoglobin; IRI, immunoreactive insulin; PCR, protein catabolic rate; n.s., not significant.

**Table 3.** Multiple regression analysis with various fat masses as independent variables and with the atherogenic index or triglycerides as the dependent variable

| Variable | $\beta$ coefficient | *t*-value | *P* |
|---|---|---|---|
| Dependent variable, AI[a] | | | |
| Body fat mass | 0.008 | 0.20 | 0.84 |
| SFA | 0.005 | 0.60 | 0.55 |
| VFA | 0.011 | 2.14 | 0.04 |
| Dependent variable, triglycerides[b] | | | |
| Body fat mass | 2.276 | 1.14 | 0.26 |
| SFA | −0.464 | −1.16 | 0.25 |
| VFA | 0.756 | 2.94 | 0.005 |

[a]Multiple $R=0.41$, $F=4.18$. [b]Multiple $R=0.44$, $F=4.71$.

associated with overproduction of VLDL which might lead to hypertriglyceridaemia and hypercholesterolaemia [26]. Després *et al.* [28] also demonstrated that a high level of visceral adipose tissue was associated with low HDL cholesterol/LDL cholesterol ratio and low $HDL_2$ fraction of HDL cholesterol.

The metabolic alterations accompanying renal failure may also be responsible for dyslipidaemia and hyperinsulinaemia independent of the fat distribution in HD patients. HD patients have been reported to have a decreased concentration of hepatic triglyceride lipase [29] and an increased level of the lipoprotein lipase inhibitor [30]. These abnormalities would result in the increase of VLDL with decreasing LDL. Lee *et al.* [14] suggested that the uraemic condition affected insulin sensitivity and lipid abnormality, irrespective of abdominal adiposity. In contrast, our data raise another possibility that the presence of renal failure would modify lipid and carbohydrate metabolism by altering the fat distribution.

The role of intra-abdominal adipose tissue in the serum lipid profile of non-obese patients has been under debate. Després *et al.* [28] reported that there was little association between intra-abdominal fat, waist–hip ratio and plasma lipoproteins in non-obese patients. In contrast, Larsson *et al.* [23] demonstrated that the incidences of stroke and ischaemic heart disease were closely associated with waist–hip ratio, even in non-obese men. Furthermore, Nakamura *et al.* [13] showed that visceral fat accumulation would contribute to the development of coronary artery disease in non-obese Japanese men, and these patients had significantly higher serum lipids than the subjects without coronary artery disease. Therefore, it is not surprising that the visceral fat accumulation affected the serum lipid profile in lean HD patients.

The causes of visceral fat accumulation are considered to be related to ageing [31], heredity [32], endocrinological disturbances [33], exercise [34,35] and diet in a non-uraemic population. Further study will be required to clarify the mechanism for the increase in the intra-abdominal adiposity in HD patients. The direct effect of renal failure or the HD procedure on fat distribution might have to be considered.

In conclusion, the HD patients exhibited an excess accumulation of intra-abdominal adipose tissue relative to the healthy subjects, although the mean subcutaneous abdominal adipose tissue was lower in the HD patients than in the control subjects. This shift in abdominal fat distribution might be associated, in part, with metabolic disturbances affecting lipids, including the increased AI index and serum triglyceride level. The treatment of visceral fat accumulation is considered to be important for preventing the progression of atherosclerotic vascular diseases in HD patients.

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## References

1. Lindner A, Charra B, Sherrard DJ, Scribner BH. Accelerated atherosclerosis in prolonged maintenance hemodialysis. *N Engl J Med* 1974; 290: 697–701
2. Kawagishi T, Nishizawa Y, Konishi T *et al.* High-resolution B-mode ultrasonography in evaluation of atherosclerosis in uraemia. *Kidney Int* 1995; 48: 820–826

3. Mallick NP, Brunner EP, Jone E, Selwood NH. Analysis of causes of death and of the direction of management to improve survival. Data from European Renal Association registry (ERA-EDTA). In: Friedman EA, ed. *Death on hemodialysis*: *preventable or inevitable*? Kluwer Academic Publishers, Dordrecht, 1994; 25–33
4. Marumo F, Maeda K, Koshikawa S. ESRD registry statistics on dialysis mortality in Japan. In: Friedman EA, ed. *Death on hemodialysis*: *preventable or inevitable*? Kluwer Academic Publishers, Dordrecht, 1994; 45–54
5. Excerpts from the United States Renal Data System 1998 Annual Data Report. VI. Causes of death. *Am J Kidney Dis* 1998; 32: s81–s88
6. Rostand SG, Kirk KA, Rutsky EA. Relationship of coronary risk factors to hemodialysis-associated ischaemic heart disease. *Kidney Int* 1982; 22: 304–308
7. Cheung AK, Wu LL, Kablitz C, Leypoldt JK. Atherogenic lipids and lipoproteins in hemodialysis patients. *Am J Kidney Dis* 1993; 22: 271–276
8. Mak RHK, Defronzo RA. Glucose and insulin metabolism in uraemia. *Nephron* 1992; 61: 377–382
9. Vincenti F, Armend WJ, Abele J, Feduska NJ, Salvatierra O. The role of hypertension in hemodialysis-associated atherosclerosis. *Am J Med* 1980; 68: 363–369
10. Reaven GM. Role of insulin resistance in human disease. *Diabetes* 1988; 37: 1595–1607
11. Kaplan NM. The deadly quartet: upper-body obesity, glucose intolerance hypertriglyceridemia, and hypertension. *Arch Intern Med* 1989; 149: 1514–1520
12. Matsuzawa Y, Fujioka S, Tokunaga K, Tarui S. A novel classification: visceral fat obesity and subcutaneous fat obesity. In: Berry EM, Eliahou HE, Blondheim SH, Shafrir E, eds. *Advances in obesity research V*. John Libbey, London, 1987; 92–96
13. Nakamura T, Tokunaga K, Shimomura I *et al.* Contribution of visceral fat accumulation to the development of coronary artery disease in non-obese men. *Atherosclerosis* 1994; 107: 239–246
14. Lee P, O'Neal D, Murphy B, Best J. The role of abdominal adiposity and insulin resistance in dyslipidemia of chronic renal failure. *Am J Kidney Dis* 1997; 29: 54–65
15. Fernström A, Hylander B, Moritz A, Jacobsson H, Rössner S. Increase of intra-abdominal fat in patients treated with continuous ambulatory peritoneal dialysis. *Perit Dial Int* 1998; 18: 166–171
16. Formica C, Atkinson MG, Nyulasi I, McKay J, Heale W, Seeman E. Body composition following hemodialysis: studies using dual-energy X-ray absorptiometry and bioelectrical impedance analysis. *Osteoporosis Int* 1993; 3: 192–197
17. Abrahamsen B, Hansen TB, Høgsberg IM, Pedersen FB, Beck-Nielsen H. Impact of hemodialysis on dual X-ray absorptiometry, bioimpedance measurements, and anthropometry. *Am J Clin Nutr* 1996; 63: 80–86
18. Depner TA, Daugirdas JT. Equations for normalized protein catabolic rate based on two-point modeling of hemodialysis urea kinetics. *J Am Soc Nephrol* 1996; 7: 780–785
19. Fujioka S, Matsuzawa Y, Tokunaga K, Tarui S. Contribution of intra-abdominal fat accumulation to impairment of glucose and lipid metabolism in human obesity. *Metabolism* 1987; 36: 54–59
20. Huebert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow up of participants in the Framingham Heart Study. *Circulation* 1983; 67: 968–977
21. Kaizu Y, Tsunega Y, Yoneyama T *et al.* Overweight as another nutritional risk factor for the long-term survival of non-diabetic hemodialysis patients. *Clin Nephrol* 1998; 50: 44–50
22. Kissebah AH, Vydelingum N, Murray R *et al.* Relation of body fat distribution to metabolic complications of obesity. *J Clin Endoclinol Metab* 1982; 54: 254–260
23. Larsson B, Svärdsudd K, Welin L, Wilhelmsen L, Björntorp P, Tibblin G. Abdominal adipose tissue distribution, obesity, and risk of cardiovascular disease and death: 13 year follow up of participants in the study of men born in 1913. *Br Med J* 1984; 288: 1401–1404
24. Borkan GA, Gerzof SG, Robbins AH, Hults DE, Silbert CK, Silbert JE. Assessment of abdominal fat content by computed tomography. *Am J Clin Nutr* 1982; 36: 172–177
25. Després JP, Lemieux S, Lamarche B *et al.* The insulin resistance–dyslipidemic syndrome: contribution of visceral obesity and therapeutic implications. *Int J Obesity* 1995; 19: s76–s86
26. Kissebah AH, Krakower GR. Regional adiposity and morbidity. *Physiol Rev* 1994; 74: 761–811
27. Rebuffé-Scrive M, Andersson O, Olbe L, Björntorp P. Metabolism of adipose tissue in intraabdominal depots of non-obese men and women. *Metabolism* 1989; 38: 453–461
28. Després JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis* 1990; 10: 497–511
29. Mordasini R, Frey F, Flury W, Klose G, Greten H. Selective deficiency of hepatic triglyceride lipase in uraemic patients. *N Engl J Med* 1977; 297: 1362–1366
30. Murase T, Cattran DC, Rubenstein B, Steiner G. Inhibition of lipoprotein lipase by uraemic plasma, a possible cause of hypertriglyceridemia. *Metabolism* 1975; 24: 1279–1286
31. Enzi G, Gasparo M, Biondetti PF, Fiore D, Semisa M, Zurlo F. Subcutaneous and visceral fat distribution according to sex, age, and overweight, evaluated by computed tomography. *Am J Clin Nutr* 1986; 44: 739–746
32. Bouchard C, Pérusse L, Leblanc C, Tremblay A, Thériault G. Inheritance of the amount and distribution of human body fat. *Int J Obesity* 1988; 12: 205–215
33. Björntorp P. The regulation of adipose tissue distribution in humans. *Int J Obesity* 1996; 20: 291–302
34. Després JP, Pouliot MC, Moojani S *et al.* Loss of abdominal fat and metabolic response to exercise training in obese women. *Am J Physiol* 1991; 261: E159–E167
35. Shimomura I, Tokunaga K, Kotani K *et al.* Marked reduction of acyl-CoA synthetase activity and mRNA in intra-abdominal visceral fat by physical exercise. *Am J Physiol* 1993; 265: E44–E50
36. Keno Y, Matsuzawa Y, Tokunaga K *et al.* High sucrose diet increases visceral fat accumulation in VMH-lesioned obese rats. *Int J Obesity* 1992; 15: 205–211

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